Supporting Information

Azofuran activation for annulative rearrangement enabled by gold(I)/Brønsted acid relay catalysis

Qian Rao,[a,1] Yin Zhang,[a,1] Yin-Ping Liu,[a] Bo Jiang,[a,*] Xiang Wang,[b] Shu-Jiang Tu,[a,*] Wen-Juan Hao[a,*]

[a]School of Chemistry & Materials Science, Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou 221116, P. R. China. E-mail: jiangchem@jsnu.edu.cn (BJ); laotu@jsnu.edu.cn (SJT); wjhao@jsnu.edu.cn (WJH)

[b]School of Chemistry and Chemical Engineering, Huaiyin Normal University, Huaian 223300, People's Republic of China

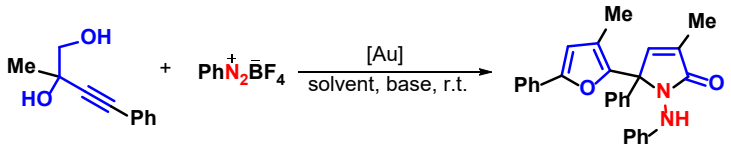
[1]These author contributed equally

Table of Contents

General Information

^{1}H NMR (^{13}C NMR) spectra were measured on a Bruker DPX 400 MHz spectrometer in $CDCl_3$ (DMSO-d_6) with chemical shift (δ) given in ppm relative to TMS as internal standard [(s = singlet, d = doublet, t = triplet, brs = broad singlet, m = multiple), coupling constant (*Hz*)]. HRMS (ESI) was determined by using microTOF-QII HRMS/MS instrument (BRUKER). X-Ray crystallographic analysis was performed with a Siemens SMART CCD and a Siemens P4 diffractometer.

Table S1. Optimization Conditions for Forming **3a**[a]



1a 2a 3a

entry	[Au] (5.0 mol %)	solvent	base	yield[b] (%)
1	JohnPhosAu(MeCN)SbF_6	DCE	-	50
2	XphosAu(TA-H)OTf	DCE	-	45
3	PPh_3AuNTf_2	DCE	-	43
4	$IPrAuNTf_2$	DCE	-	trace
5	AuCl	DCE	-	trace
6	JohnPhosAu(MeCN)SbF_6	1,4-dioxane	-	trace
7	JohnPhosAu(MeCN)SbF_6	DMF	-	trace
8	JohnPhosAu(MeCN)SbF_6	THF	-	trace
9	JohnPhosAu(MeCN)SbF_6	toluene	-	trace
10	JohnPhosAu(MeCN)SbF_6	acetone	-	trace
11	JohnPhosAu(MeCN)SbF_6	DCM	-	45
12	JohnPhosAu(MeCN)SbF_6	dry DCE	-	55
13	JohnPhosAu(MeCN)SbF_6	dry DCE	-	32[c]
14	JohnPhosAu(MeCN)SbF_6	dry DCE	$NaHCO_3$	69
15	JohnPhosAu(MeCN)SbF_6	dry DCE	Na_2CO_3	59
16	JohnPhosAu(MeCN)SbF_6	dry DCE	K_2CO_3	55
17	JohnPhosAu(MeCN)SbF_6	dry DCE	NaOAc	58
18	JohnPhosAu(MeCN)SbF_6	dry DCE	K_3PO_4	56
19	JohnPhosAu(MeCN)SbF_6	dry DCE	Et_3N	N. R.

20	JohnPhosAu(MeCN)SbF_6	dry DCE	pyridine	trace
21	JohnPhosAu(MeCN)SbF_6	dry DCE	DBU	trace
22	JohnPhosAu(MeCN)SbF_6	dry DCE	$NaHCO_3$	67[d]
23	JohnPhosAu(MeCN)SbF_6	dry DCE	$NaHCO_3$	60[e]

[a]Reaction conditions: **1a** (0.2 mmol), **2a** (0.1 mmol), base (0.05 mmol, 0.5 equiv), solvent (2.0 mL), room temperature for 12 h; [b]Isolated yield. [c]4 Å molecular sieve (50 mg). [d]use of $NaHCO_3$ (0.6 equiv). [e]use of $NaHCO_3$ (0.9 equiv).

At the outset of the investigations, 3-yne-1,2-diol **1a** and phenyldiazonium tetrafluoroborate **2a** were selected as model substrates for the parameter optimization, as depicted in Table S1. The reaction of **1a** with **2a** in a 2:1 mol ratio worked readily in 1,2-dichloroethane (DCE) at room temperature by using JohnPhosAu(MeCN)SbF_6 (5.0 mol %) as a catalyst, and an unexpected furan-2-yl-substituted pyrrol-2-one product **3a** was obtained in 50% yield (Table S1, entry S1). Several other gold catalysts often used in catalytic transformations, such as XphosAu(TA-H)OTf, PPh_3AuNTf_2, AuCl, and $IPrAuNTf_2$, were then investigated. The results revealed that the former two could drive the conversion of **1a** with **2a** into **3a**, but both demonstrated lower catalytic capabilities and thus provided lower yields compared with JohnPhosAu(MeCN)SbF_6 (entries S2-S3 vs entry S1); in contrast, the latter two completely suppressed the generation of **3a** (entries S4-S5). Taking JohnPhosAu(MeCN)SbF_6 as the catalyst, the effect of solvents was then examined and several other aprotic solvents such as 1,4-dioxane, *N*,*N*-dimethylformamide (DMF), tetrahydrofuran (THF), toluene, acetone, and dichloromethane (DCM) were screened (entries S6-S11). However, the desired product **3a** was hardly detected when the former five solvents were independently employed in this reaction. In another case of DCM, the reaction gave product **3a** in 45%, which is less than DCE (entry S12). Notably, dry DCE as the solvent ameliorated the reaction, leading to a 55% yield of **3a**. The use of a 4 Å molecular sieve (MS) as a water absorbent was unfavorable for this transformation, probably because the presence of some amount of water could accelerate the dissolution of diazonium *s*alts. Considering the release of stoichiometric amounts of HBF_4 as a strong Brønsted acid that could decompose the furan ring in the reaction system, the removal of excess HBF_4 to a catalytic dosage may improve the efficiency of the reaction. Along this line, a number of bases, such as $NaHCO_3$, Na_2CO_3, K_2CO_3, NaOAc, K_3PO_4, Et_3N, pyridine, and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU), were next screened for this transformation (entries S14–S21): inorganic bases proved to be beneficial

to this reaction (entries S14–S18); in contrast, organic bases were found to be ineffective, and their use in fact completely inhibited the target (entries S19–S21); and of these inorganic bases, the use of 0.5 equiv of $NaHCO_3$ made this reaction work more efficiently, furnishing product **3a** in a higher yield of 69% (entry S14). Further increasing the amount of $NaHCO_3$ resulted in reduced yields (entries S22-S23). From these results, a catalytic amount of HBF_4 is believed to favor azofuran activation for 1,6-addition and subsequent rearrangement.

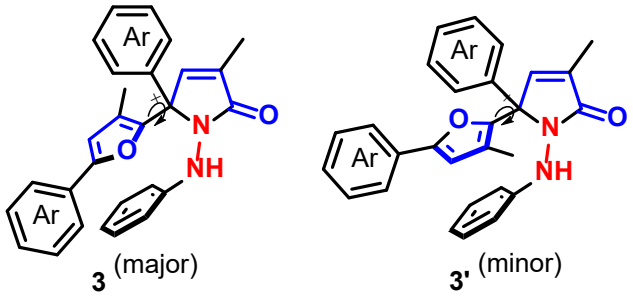


Figure S1. Atropisomerism of Product **3a**

Obvious atropisomerism is observed in this protocol, which is caused by steric repulsion of the non-symmetric furan ring, and its rotation around a single $C(sp^3)$-$C(sp^2)$ bond is restricted by the arylamino group and the phenyl ring (Figure S1). This could be supported by the crystal structure of **3e** determined by X-ray diffraction analysis (Figure S2)

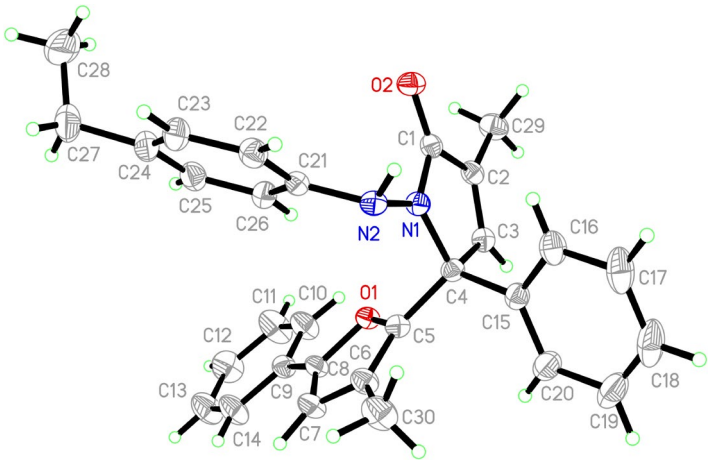
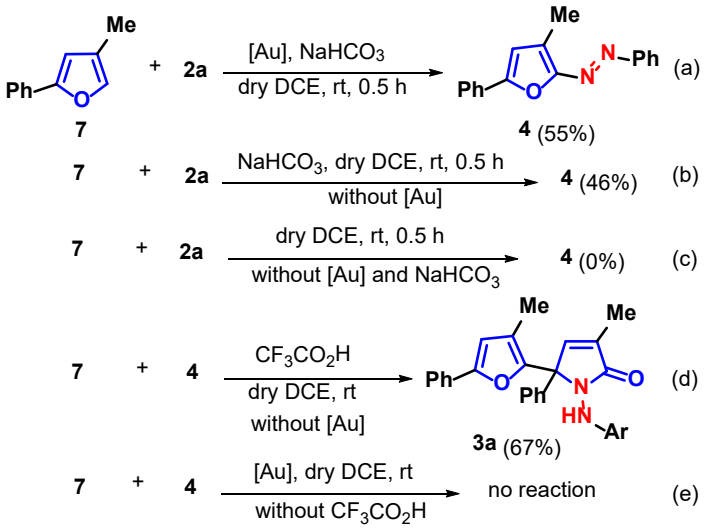


Figure S2. The ORTEP Drawing of **3e** (The ellipsoid contour 30% probability levels)

A single crystal **3e** was obtained by slowly evaporating dichloromethane solvent at room temperature under the air conditions.



Scheme S1. Control Experiments

Synthesis of Substrates 1 and 2

Preparation of Alkynyl-1,2-diols 1

Alkynyl-1,2-diols **1a-1k** were prepared according to the reported procedures.[1-3] and their characterization data are in agreement with the literature.

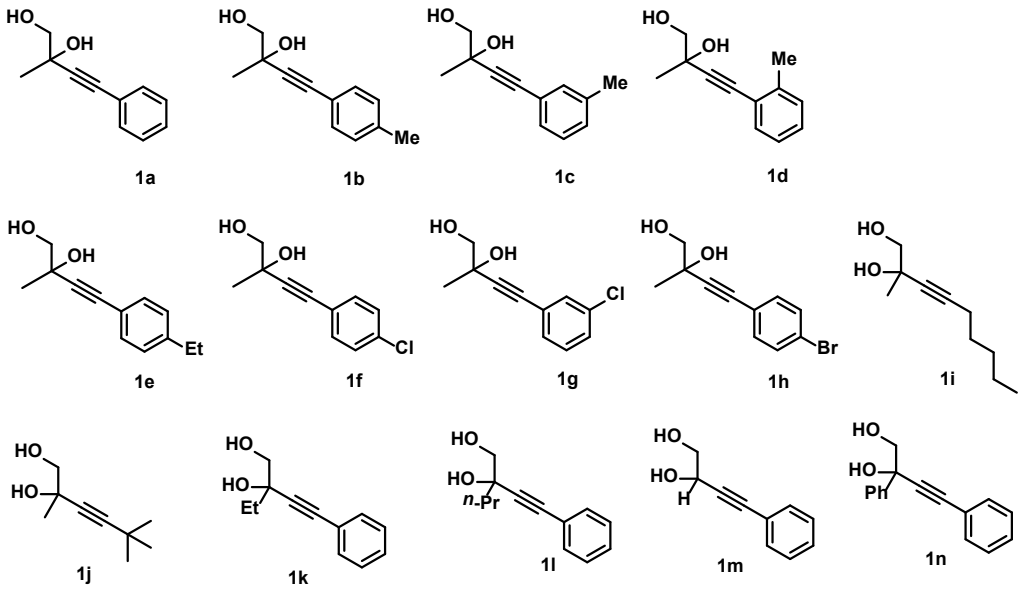


Figure S3. Substrate Scope of Alkynyl-1,2-diols **1**

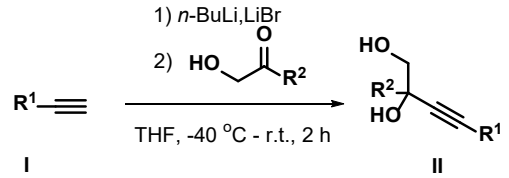


Figure S4. Synthesis of Compounds **1a-1n**

Alkynyl-1,2-diols **II** were prepared based on the reported procedures.[4]

Step: A solution of alkyne (19.23 mmol of 1-hexyne, phenylacetylene, cyclopropylacetylene, ethynyltrimethylsilane) in anhydrous THF (3 mL) was added dropwise under nitrogen to a stirred, cooled (-40 °C) mixture of BuLi (12.1 mL of a 1.6 M solution in hexanes, 19.35 mmol) in anhydrous THF (9 mL) and anhydrous hexane (14 mL). To the resulting mixture, maintained at -40 °C, was added, with stirring, a solution of LiBr (0.68 g, 7.8 mmol) in THF (3 mL). After 0.5 h, the corresponding **I** (7.34 mmol of α-hydroxyacetophenone or α-hydroxyacetone), diluted in anhydrous THF (3 mL), was slowly added under nitrogen at the same temperature. The resulting mixture was stirred for additional 2 h and then allowed to warm up to room temperature. After quenching with a saturated solution of NH_4Cl, the mixture was extracted with Et_2O (x3). The combined organic layers were washed with water and then dried over $MgSO_4$. After filtration, the solvent was evaporated to obtain crude that was purified by column chromatography on silica gel. Analytical samples of compounds **II**, **1a-1k** were obtained after column chromatography.

Preparation of Aryldiazonium Salts 2

Aryldiazonium salts **2a-2q** were prepared based on the reported procedures.[5]

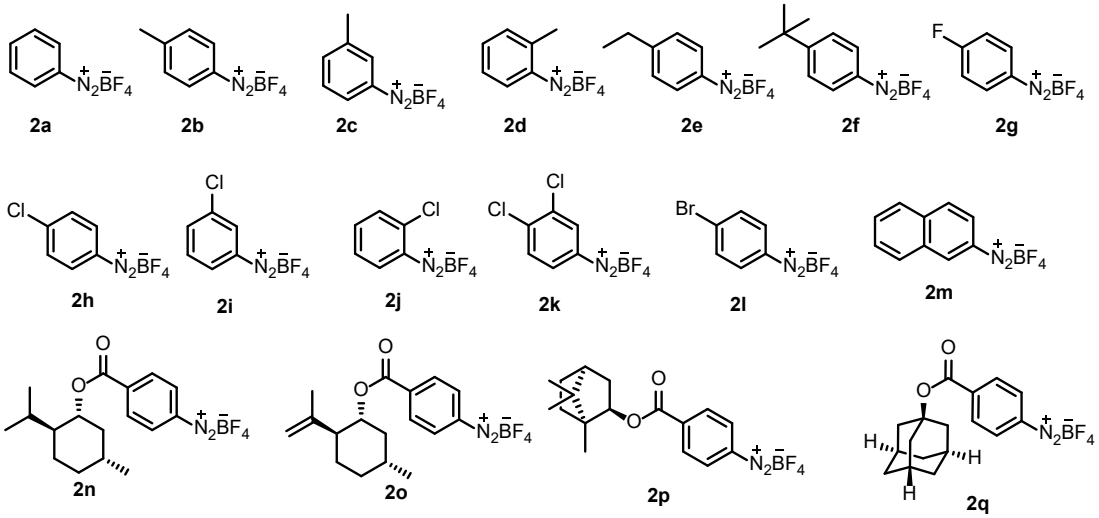


Figure S5. Substrate Scope of Aryldiazonium salts **2**

Application of 2*H*-Pyrrolone-Based Cyclic Products

Gram-Scale Experiment for the Synthesis of Product 3h

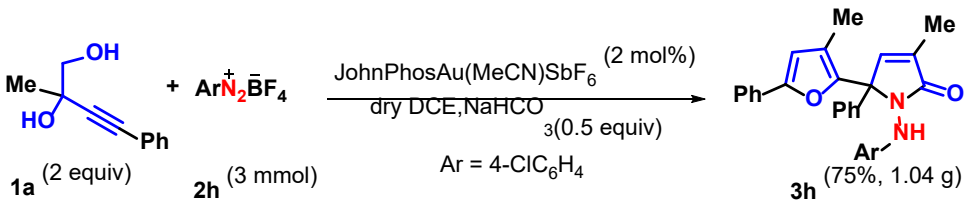


Figure S6. Gram-Scale Synthesis of Compounds **3h**

To a 100-mL pressure tube under air conditions, 2-methyl-4-phenylbut-3-yne-1,2-diol (**1a**, 6 mmol, 2 equiv, 0.94 g), benzenediazonium tetrafluoroborate (**2h**, 3 mmol, 1 equiv, 0.57 g), $NaHCO_3$ (0.05 mmol, 0.5 equiv, 0.13 g), JohnPhosAu(MeCN)SbF_6 (2.0 mol%, 46.32 mg), dry 1,2-dichloroethane (40 mL) were successively added. The mixture was stirred at room temperature for about 6 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 5:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**3h**, 1.04 g, 75% yield) as white solid.

General Procedure for the Synthesis of Product 6

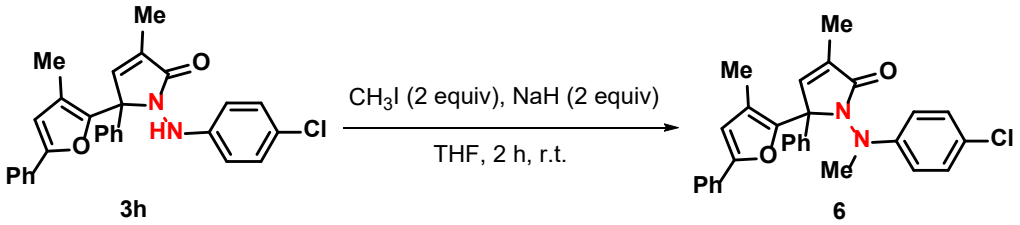
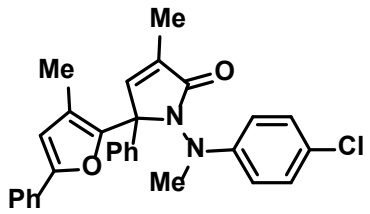


Figure S7. Synthesis of Compound **6**

To a solution of 1-((4-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (**3h**, 0.2 mmol, 1 equiv, 91.2 mg) in THF (2 mL) at 0 °C, NaH (0.4 mmol, 2 equiv, 9.6 mg) was added. The reaction mixture was stirred for 0.5 hours at room temperature. The solution was added with CH_3I (0.4 mmol, 2.0 equiv, 56.78 2mg) and stirred for 12 hours. The reaction mixture was then quenched with saturated aq. NH_4Cl and extracted with ethyl acetate (3 x 20 mL). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and concentrated. The residue was purified by column chromatography (eluent, petroleum ether/ethyl acetate =8:1) on silica gel to afford **6** (78.4 mg, 85% yield).

1-((4-chlorophenyl)(methyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (6)



white solid (39.9 mg, 85% yield); mp:160-162 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.63 (d, J = 7.2 Hz, 1H), 7.51 (d, J = 6.4 Hz, 1H), 7.41 (d, J = 9.2 Hz, 5H), 7.42-730 (m, 2H), 7.25 (s, 1H), 7.05 (s, 1H), 6.98-6.93 (m, 2H), 6.54 (s, 1H), 6.44 (d, J = 6.4 Hz, 2H), 6.33 (s, 1H), 3.27 (s, 1H), 3.16 (s, 2H), 2.10 (s, 3H), 1.74 (s, 2H), 1.55 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.2, 152.3, 151.9, 148.2, 144.0, 143.8, 137.2, 131.0, 130.4, 128.9, 128.7, 128.6, 128.4, 127.7, 127.6, 124.3, 123.9, 122.5, 114.9, 110.0, 70.9, 41.6, 11.8, 11.5; IR (KBr, *v*, cm^{-1}): 2958, 1698, 1597, 1490, 1447, 760, 692; HRMS (ESI -TOF) *m/z*: $[M+H]^+$ Calcd for $C_{29}H_{26}ClN_2O_2$ 469.1683; Found 469.1698.

Mechanism Details

Control Experiment A

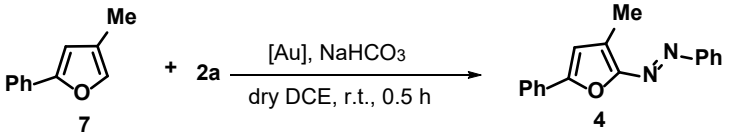


Figure S8. Control Experiment A

To a 10-mL pressure tube under air conditions, 4-methyl-2-phenylfuran[6] (**7**, 0.1 mmol, 1 equiv, 15.8 mg), benzenediazonium tetrafluoroborate (**2a**, 0.1 mmol, 1 equiv, 19.2 mg), $NaHCO_3$ (0.05 mmol, 0.5 equiv, 4.2 mg), JohnPhosAu(MeCN)SbF_6 (2 mol%, 1.54 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 0.5 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 50:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**4**, 15.5 mg, 55% yield) as orange solid.

Control Experiment B

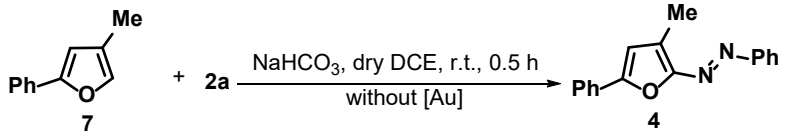


Figure S9. Control Experiment B

To a 10-mL pressure tube under air conditions, 4-methyl-2-phenylfuran (**7**, 0.1 mmol, 1 equiv, 15.8 mg), benzenediazonium tetrafluoroborate (**2a**, 0.1 mmol, 1 equiv, 19.2 mg), (0.05 mmol, $NaHCO_3$ (0.05 mmol, 0.5 equiv, 4.2 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 0.5 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 50:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**4**, 12.9 mg, 46% yield) as orange solid.

Control Experiment C

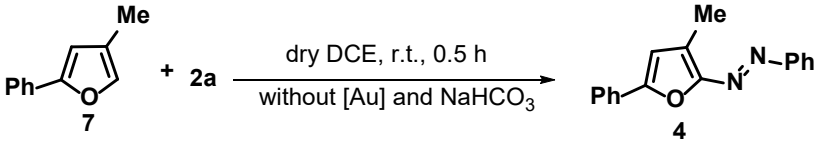


Figure S10. Control Experiment C

To a 10-mL pressure tube under air conditions, 4-methyl-2-phenylfuran (**7**, 0.1 mmol, 1 equiv, 15.8 mg), benzenediazonium tetrafluoroborate (**2a**, 0.1 mmol, 1 equiv, 19.2 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 0.5 hours. The desired product **4** was not detected by TLC.

Control Experiment D

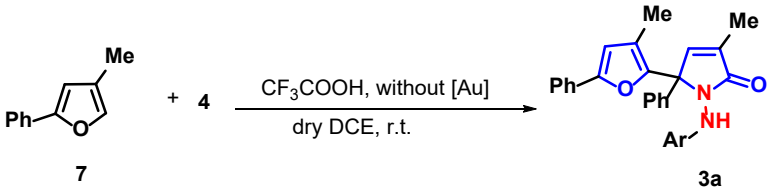


Figure S11. Control Experiment D

To a 10-mL pressure tube under air conditions, 4-methyl-2-phenylfuran (**7**, 0.1 mmol, 1 equiv, 15.8 mg), (*E*)-1-(3-methyl-5-phenylfuran-2-yl)-2-phenyldiazene (**4**, 0.1 mmol, 1 equiv, 26.2 mg), CF_3COOH (0.1 mmol, 1 equiv, 11.4 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 2 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 5:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**3a**, 28.1 g, 67% yield) as white solid.

Control Experiment E

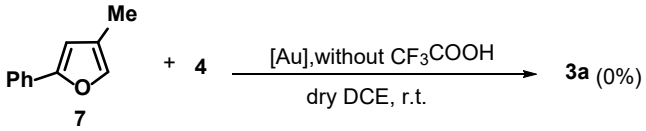


Figure S12. Control Experiment E

To a 10-mL pressure tube under air conditions, 4-methyl-2-phenylfuran (**1a**, 0.1 mmol, 1 equiv, 15.8 mg), (*E*)-1-(3-methyl-5-phenylfuran-2-yl)-2-phenyldiazene (**4**, 0.1 mmol, 1 equiv, 26.2 mg), JohnPhosAu(MeCN)SbF_6 (5.0 mol%, 3.86 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The desired product **3a** was not detected by TLC.

Preparation of 2*H*-Pyrrolone-Based Cyclic Products

General Procedure for the Synthesis of Products 3a-3bb

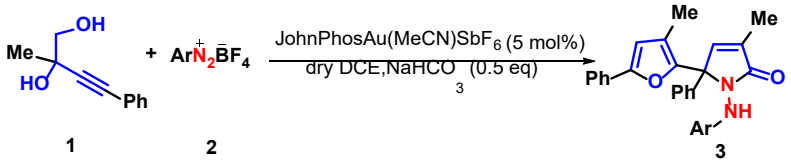
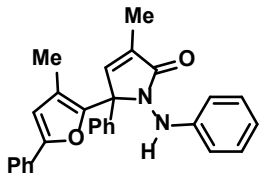


Figure S13. Synthesis of Compounds **3**

To a 10-mL pressure tube under air conditions, 2-methyl-4-phenylbut-3-yne-1,2-diol (**1a**, 0.2 mmol, 2.0 equiv, 31.2 mg), benzenediazonium tetrafluoroborate (**2a**, 0.1 mmol, 1 equiv, 19.2 mg), $NaHCO_3$ (0.05 mmol, 0.5 equiv, 4.2 mg), JohnPhosAu(MeCN)SbF_6 (5.0 mol%, 3.86 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 12 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 5:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**3a**, 29.0 mg, 69% yield) as white solid.

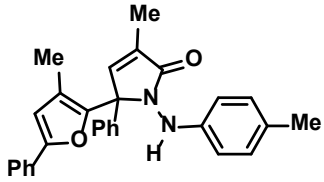
3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (3a)



white solid (29.0mg, 69% yield); mp: 205-206 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.53 (d, J = 6.8 Hz, 2H), 7.36 (s, 5H), 7.29 (s, 2H), 7.28 (s, 1H), 7.08 (s, 1H), 6.96-6.92 (m, 2H), 6.70-6.66 (m,

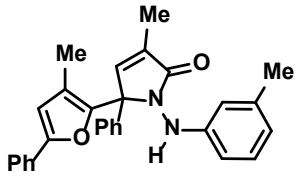
1H), 6.40 (d, J = 7.6 Hz, 2H), 6.36 (s, 1H), 6.22 (s, 1H), 2.07 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.0, 146.6, 144.5, 143.7, 137.4, 130.4, 129.1, 128.7, 128.6, 128.4, 127.5, 126.9, 123.8, 120.5, 112.9, 110. 0, 71.0, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3268, 3029, 1698, 1602, 1496, 1447, 762, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{23}N_2O_2$ 419.1760; Found 419.1765.

3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1-(p-tolylamino)-1,5-dihydro-2H-pyrrol-2-one (3b)



white solid (21.6 mg, 60% yield); mp: 202-204 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.52 (d, J = 8.0 Hz, 2H), 7.37 (d, J = 7.6 Hz, 5H), 7.34 (s, 2H), 7.28 (s, 1H), 7.06 (s, 1H), 6.75 (d, J = 8.0 Hz, 2H), 6.38 (s, 1H), 6.31 (d, J = 8.0 Hz, 2H), 6.00 (s, 1H), 2.11 (s, 3H), 2.04 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.0, 144.8, 144.5, 143.4, 137.6, 130.5, 129.8, 129.3, 129.1, 128.7, 128.4, 127.6, 127.0, 123.8, 113.3, 110.1, 71.1, 20.5, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3266, 2985, 1700, 1598, 1512, 1447, 761, 693; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{29}H_{25}N_2O_2$ 433.1916; Found 433.1919.

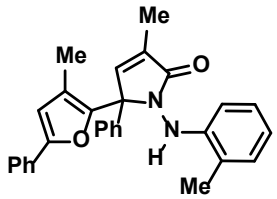
3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1-(m-tolylamino)-1,5-dihydro-2H-pyrrol-2-one (3c)



white solid (25.2 mg, 58% yield); mp: 210-211 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.53 (d, J = 8.0 Hz, 2H), 7.37 (d, J = 7.2 Hz, 5H), 7.35 (s, 2H), 7.28 (s, 1H), 7.24 (s, 1H), 7.06 (s, 1H), 6.86–6.82 (m, 1H), 6.49 (d, J = 7.6 Hz, 1H), 6.36 (s, 1H), 6.24 (d, J = 8.4 Hz, 1H), 6.12 (s, 1H), 2.07 (s, 3H), 1.97 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.0, 146.7, 144.6, 143.5, 138.5,137.6, 131.5, 130.5, 129.2, 128.7, 128.5, 128.4, 127.6, 126.9, 123.8, 121.4, 113.6, 110.3,

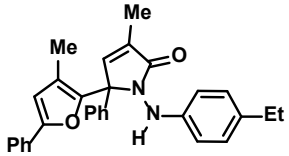
110.0, 71.1, 21.4, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3263, 2895, 1697, 1654, 1595, 1458, 760, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{29}H_{25}N_2O_2$ 433.1916; Found 433.1922.

3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1-(o-tolylamino)-1,5-dihydro-2H-pyrrol-2-one (3d)



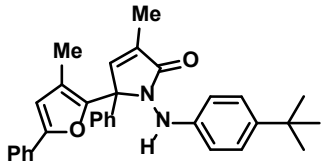
white solid (24.0 mg, 55% yield); mp: 170-171 °C; ^1H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.50 (d, J = 7.6 Hz, 2H), 7.37 (s, 5H), 7.34 (s, 2H), 7.28 (s, 1H), 7.08 (s, 1H), 6.89 (d, J = 7.2 Hz, 1H), 6.71-6.68 (m, 1H), 6.62-659 (m, 1H), 6.31 (s, 1H), 6.13 (d, J = 8.0 Hz, 1H), 6.03 (s, 1H), 2.10 (s, 3H), 2.08 (s, 3H), 1.54 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 151.9, 148.2, 144.6, 144.2, 137.7, 134.1, 131.5, 130.5, 130.0, 129.1, 128.7, 128.3, 127.5, 127.2, 126.8, 126.5, 123.8, 120.2, 111.9, 110.0, 71.2, 17.0, 11.6, 11.0; IR (KBr, *v*, cm^{-1}): 3274, 2924, 1763, 1697, 1484, 1447, 748, 695; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{29}H_{25}N_2O_2$ 433.1916; Found 433.1919.

1-((4-ethylphenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3e)



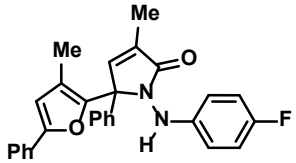
white solid (27.7 mg, 62% yield); mp: 215-216 °C; ^1H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.57 (d, J = 7.6 Hz, 2H), 7.42 (d, J = 7.2 Hz, 5H), 7.40 (s, 2H), 7.33 (s, 1H), 7.31-7.24 (m, 1H), 7.12 (s, 1H), 6.83 (d, J = 7.6 Hz, 2H), 6.42 (d, J = 6.4 Hz, 2H), 6.39 (s, 1H), 2.50-2.44 (m, 2H), 2.11 (s, 3H), 1.66 (s, 3H), 1.14-1..10 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.0, 144.7, 144.6,143.4, 137.6, 136.3, 131.6, 130.5, 129.1, 128.7, 128.4, 128.1, 127.5, 127.0, 126.7, 123.8, 113.3, 110.1, 71.1, 28.0, 15.8, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3269, 2962, 1698, 1513, 1446, 1262, 742, 668; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{30}H_{27}N_2O_2$ 447.2073; Found 447.2077.

1-((4-(tert-butyl)phenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3f)



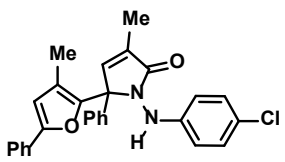
white solid (28.6 mg, 60% yield); mp: 220-221 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.48 (d, J = 7.6 Hz, 2H), 7.35 (d, J = 6.0 Hz, 5H), 7.32 (s, 2H), 7.24 (d, J = 7.2 Hz, 1H), 7.06 (s, 1H), 6.95 (d, J = 8.0 Hz, 2H), 6.37 (s, 1H), 6.35 (d, J = 2.8 Hz, 2H), 2.06 (s, 3H), 1.63 (s, 3H), 1.14 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.9, 152.1, 144.6, 144.2, 143.4, 143.2, 137.6, 131.6, 130.5, 129.1, 128.7, 128.4, 127.5, 127.0, 125.5, 123.8, 122.3, 113.0, 110.0, 71.1, 33.9, 31.5, 11.6, 11.4; IR (KBr, *v*, cm^{-1}): 3256, 2960, 1696, 1611, 1508, 1484, 761, 693; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{32}H_{31}N_2O_2$ 475.2386; Found 475.2391.

1-((4-fluorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3g)



white solid (31.5 mg, 72% yield); mp: 161-163 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 8.0 Hz, 2H), 7.39 (d, J = 6.8 Hz, 2H), 7.35 (d, J = 7.2 Hz, 5H), 7.22 (s, 1H), 7.07 (s, 1H), 6.65-6.59 (m, 2H), 6.36 (s, 1H), 6.35-6.32 (m, 2H), 6.20 (d, J = 4.8 Hz, 1H), 2.06 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 157.5 (J_{CF}^1 = 236.2 Hz), 152.1, 151.4, 144.5, 143.6, 142.8 (J_{CF}^4 = 2.5 Hz), 137.4, 131.5, 130.4, 129.2, 128.8, 128.5, 127.7, 126.9, 123.8, 115.2 (J_{CF}^2 = 27.7 Hz), 114.3 (J_{CF}^3 = 7.9 Hz), 110.0, 71.1, 11.6, 11.2; ^{19}F NMR (376 MHz, $CDCl_3$) (δ, ppm): -124.6; IR (KBr, *v*, cm^{-1}): 3265, 2960, 1697, 1507, 1490, 1447, 760, 691; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{28}H_{22}FN_2O_2$ 437.1665; Found 437.1669.

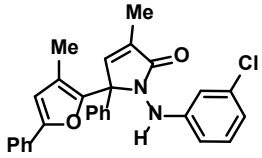
1-((4-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3h)



white solid (36.0 mg, 79% yield); mp: 189-190 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 7.6 Hz, 2H), 7.38-7.33 (m, 5H), 7.33 (s, 1H), 7.29 (s, 1H), 7.25 (s, 1H), 7.07 (s, 1H), 6.88 (d, J =

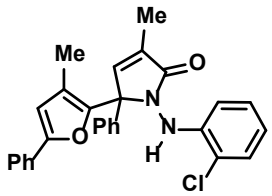
7.6 Hz, 2H), 6.38 (s, 1H), 6.30 (d, J = 8.4 Hz, 2H), 6.21 (s, 1H), 2.06 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.1, 145.6, 144.4, 143.9, 137.3, 130.4, 129.2, 128.8, 128.6, , 128.5, 127.7, 126.9, 125.0, 123.8, 122.6, 114.1, 110.1, 71.1, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3260, 2958, 1698, 1597, 1490, 1447, 760, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{22}ClN_2O_2$ 453.1370; Found 453.1375.

1-((3-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3i)



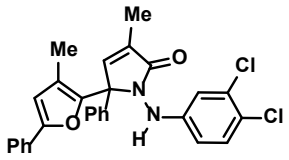
white solid (34.7 mg, 76% yield); mp: 206-207 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 7.6 Hz, 2H), 7.36 (d, J = 6.4 Hz, 5H), 7.33 (s, 2H), 7.24 (s, 1H), 7.08 (s, 1H), 6.81 (m, 1H), 6.61 (d, J = 8.0 Hz, 1H), 6.40 (s, 1H), 6.37 (s, 1H), 6.31 (s, 1H), 6.27 (d, J = 8.2 Hz, 1H), 2.08 (s, 3H), 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.3, 148.1, 144.2, 143.8, 137.2, 134.5, 130.4, 129.7, 129.2, 128.7, 128.6, 127.7, 126.9, 123.9, 120.40, 120.37, 113.0, 111.1, 110.0, 71.1, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3256, 2987, 1698, 1596, 1480, 1446, 759, 690; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{22}ClN_2O_2$ 453.1370; Found 453.1375.

1-((2-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3j)



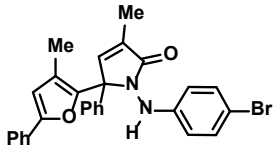
white solid (34.2 mg, 75% yield); mp: 190-191 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.52 (d, J = 6.4 Hz, 2H), 7.37 (s, 5H), 7.35 (s, 2H), 7.28 (s, 1H), 7.10 (d, J = 9.2Hz, 2H), 6.74-6.70 (m, 1H), 6.59 (d, J = 7.6 Hz, 1H), 6.57-6.52 (m, 1H), 6.34 (s, 1H), 6.16 (s, 1H), 2.08 (s, 3H), 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.4, 152.2, 144.4, 143.6, 142.3, 137.2, 131.6, 130.4, 129.3, 129.0, 128.8, 128.6, 127.7, 127.3, 126.8, 123.8, 120.6, 118.5, 113.3, 110.0, 71.1, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3268, 3010, 1701, 1593, 1447, 1265, 759, 745; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{28}H_{22}ClN_2O_2$ 453.1370; Found 453.1374.

1-((3,4-dichlorophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3k)



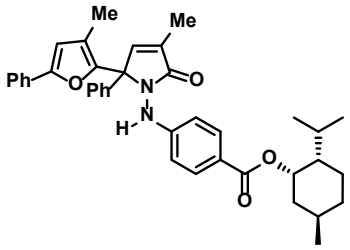
white solid (34.3 mg, 70% yield); mp: 239-240 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.50 (d, J = 8.0 Hz, 2H), 7.36 (d, J = 6.0 Hz, 5H), 7.33 (s, 2H), 7.28 (s, 1H), 7.08 (s, 1H), 6.93 (d, J = 8.8 Hz, 1H), 6.39 (s, 1H), 6.37 (s, 2H), 6.22 (d, J = 8.8 Hz, 1H), 2.06 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.6, 152.4, 146.5, 144.1, 137.0, 132.6, 130.24, 130.16, 129.3, 128.8, 127.8, 126.9, 126.5, 123.9, 123.2, 114.6, 112.5, 110.0, 100.0, 71.0, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3266, 2987, 1700, 1593, 1448, 1264, 866, 745; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{28}H_{21}Cl_2N_2O_2$ 487.0987; Found 487.0981.

1-((4-bromophenyl)amino)-3-methyl-5-(3-methyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3l)



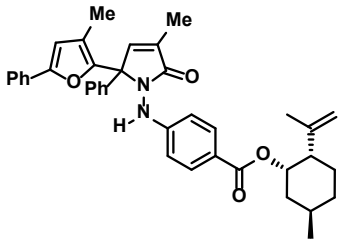
white solid (35.4 mg, 71% yield); mp: 201-202 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.50 (d, J = 7.6 Hz, 2H), 7.38-7.35 (m, 5H), 7.32 (s, 1H), 7.29 (s, 1H), 7.26 (s, 1H), 7.08 (s, 1H), 7.02 (d, J = 8.4 Hz, 2H), 6.38 (s, 1H), 6.26 (d, J = 8.4 Hz, 2H), 6.15 (s, 1H), 2.05 (s, 3H), 1.58 (s, 3H).; ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.2, 146.0, 144.4, 137.2, 131.5, 130.3, 129.2, 128.8, 128.6, 127.7, 126.9, 123.8, 114.7, 112.5, 110.1, 71.0, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3284, 3008, 1689, 1586, 1448, 1264, 745, 693; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{22}BrN_2O_2$ 497.0865; Found 497.0871.

(1S,2R,5S)-2-isopropyl-5-methylcyclohexyl 4-((4-methyl-2-(3-methyl-5-phenylfuran-2-yl)-5-oxo-2-phenyl-2,5-dihydro-1H-pyrrol-1-yl)amino)benzoate (3n)



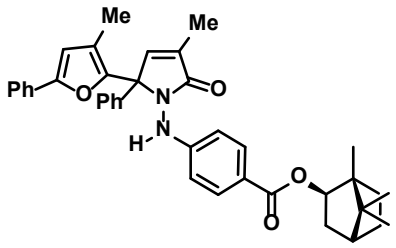
white solid (43.3 mg, 72% yield); mp: 202-203 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.66 (d, J = 8.4 Hz, 2H), 7.50 (d, J = 6.8 Hz, 2H), 7.36 (d, J = 8.0 Hz, 2H), 7.34 (s, 4H), 7.28 (s, 1H), 7.24 (s, 1H), 7.11 (s, 1H), 6.49 (s, 1H), 6.39 (d, J = 7.2 Hz, 3H), 4.84-4.78 (m, 1H), 2.08 (s, 3H), 2.04 (d, J = 12.4 Hz, 1H), 1.87 (d, J = 6.8 Hz, 1H), 1.69 (d, J = 11.2 Hz, 2H), 1.60 (d, J = 7.2 Hz, 3H), 1.49-1.43 (m, 2H), 1.11-1.00(m, 2H), 0.91-0.86 (m, 6H), 0.74 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.5, 166.0, 152.3, 150.9, 144.3, 131.0, 130.3, 129.3, 128.8, 128.7, 127.7, 123.9, 123.8, 122.6, 111.9, 110.1, 74.1, 47.3, 41.1, 34.5, 31.5, 26.5, 23.8, 22.2, 20.9, 16.7, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3262, 2969, 1698, 1597, 1490, 1448,760, 693; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{39}H_{41}N_2O_4$ 601.3066; Found 601.3066.

(1S,2R)-2-(prop-1-en-2-yl)cyclohexyl 4-((4-methyl-2-(3-methyl-5-phenylfuran-2-yl)-5-oxo-2-phenyl-2,5-dihydro-1H-pyrrol-1-yl)amino)benzoate (3o)



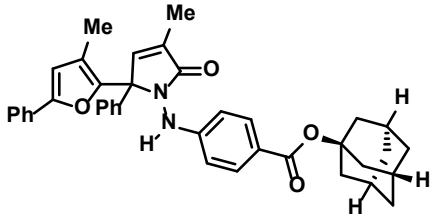
white solid (42.1 mg, 70% yield); mp: 218-219 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.61 (d, J = 8.4 Hz, 2H), 7.49 (s, 2H), 7.37 (s, 1H), 7.34 (d, J = 5.6 Hz, 5H), 7.28 (s, 1H), 7.25 (s, 1H), 7.10 (s, 1H), 6.46 (s, 1H), 6.38-6.35(m, 3H), 4.89 (s, 1H), 4.70-4.60 (m, 2H), 2.23-2.17 (m, 1H), 2.07 (s, 3H), 1.74-1.68 (m, 2H), 1.63 (s, 3H), 1.57 (s, 3H), 1.47-1.39 (m, 1H), 1.08-0.99 (m, 2H), 0.94 (s, 2H), 0.92 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.5, 166.0, 152.3, 150.8, 146.4, 144.3, 130.9, 130.3, 129.3, 128.8, 127.7, 123.8, 122.7, 111.8, 110.1, 73.8, 50.9, 40.6, 34.3, 31.5, 30.6, 22.1, 19.6, 11.6; IR (KBr, *v*, cm^{-1}): 3268, 2954, 1702, 1606, 1487, 1448,761, 693; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{39}H_{39}N_2O_4$ 599.2910; Found 599.2913.

(1R,2R,4S)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl 4-((4-methyl-2-(3-methyl-5-phenylfuran-2-yl)-5-oxo-2-phenyl-2,5-dihydro-1H-pyrrol-1-yl)amino)benzoate (3p)



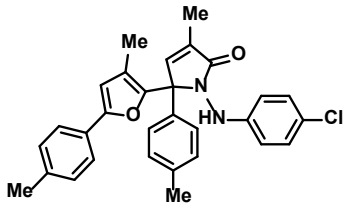
white solid (45.1 mg, 75% yield); mp: 223-225 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.66 (d, J = 8.4 Hz, 2H), 7.51 (d, J = 6.8 Hz, 2H), 7.38 (s, 1H), 7.35 (d, J = 5.6 Hz, 5H), 7.28 (s, 1H), 7.12 (s, 1H), 6.61 (s, 1H), 6.42-6.37 (m, 3H), 5.00 (d, J = 9.6 Hz, 1H), 2.42-2.38 (m, 1H), 2.09 (s, 3H), 2.01 (s, 1H), 1.76 (s, 1H), 1.70 (s, 1H), 1.60 (s, 3H), 1.33-1.21 (m, 2H), 1.03 (d, J = 14 Hz, 1H), 0.94 (s, 3H), 0.90 (s, 3H), 0.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.5, 166.8, 152.3, 150.9, 144.2, 130.8, 130.3, 129.3, 128.8, 127.7, 123.9, 122.6, 111.9, 110.1, 79.8, 49.1, 47.9, 45.1, 37.0, 28.1, 27.4, 19.8, 19.0, 13.7, 11.6; IR (KBr, *v*, cm^{-1}): 3268, 2925, 1703, 1606, 1486, 1448,761, 693; HRMS (ESI -TOF) *m/z*: [M-H]$^{-}$ Calcd for $C_{39}H_{39}N_2O_4$ 599.2910; Found 599.2909.

(3s,5s,7s)-adamantan-1-yl 4-((4-methyl-2-(3-methyl-5-phenylfuran-2-yl)-5-oxo-2-phenyl-2,5-dihydro-1H-pyrrol-1-yl)amino)benzoate (3q)



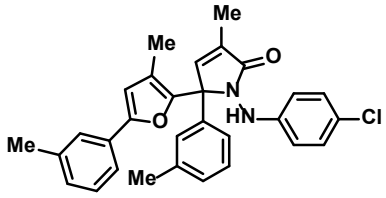
white solid (46.7 mg, 78% yield); mp:244-246 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.58 (d, J = 8.0 Hz, 2H), 7.51 (d, J = 6.8 Hz, 2H), 7.38 (s, 1H), 7.35 (d, J = 7.6 Hz, 5H), 7.28 (s, 1H), 7.25 (s, 1H), 7.09 (s, 1H), 6.53 (s, 1H), 6.35 (d, J = 8.4 Hz, 3H), 2.17 (s, 9H), 2.07 (s, 3H), 1.68 (s, 6H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.5, 166.8, 152.3, 150.9, 144.2, 130.8, 130.3, 129.3, 128.8, 127.7, 123.8, 122.62, 122.57, 111.9, 110.1, 79.8, 49.1, 47.9, 45.1, 37.0, 28.1, 27.4, 19.8, 19.0, 13.8, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3266, 2953, 1702, 1606, 1486, 1448,761, 692; HRMS (ESI -TOF) *m/z*: [M-H]$^{-}$ Calcd for $C_{39}H_{37}N_2O_4$ 597.2753; Found 597.2751.

1-((4-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-(p-tolyl)furan-2-yl)-5-(p-tolyl)-1,5-dihydro-2H-pyrrol-2-one (3r)



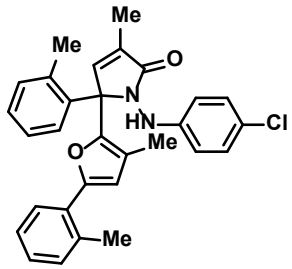
white solid (33.7 mg, 70% yield); mp: 171-172 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.42 (d, J = 7.6 Hz, 2H), 7.21 (s, 2H), 7.18 (d, J = 5.2 Hz, 4H), 7.07 (s, 1H), 6.87 (s, 1H), 6.85 (s, 1H), 6.42 (s, 1H), 6.31 (s, 2H), 6.28 (s, 1H), 2.38 (s, 3H), 2.36 (s, 3H), 2.07 (s, 3H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.3, 145.7, 144.1, 138.4, 137.6, 134.2, 129.9, 129.5, 129.3, 128.6, 127.77, 127.75, 126.8, 125.0, 123.8, 114.2, 109.4, 71.0, 21.4, 21.2, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3260, 2920, 1698, 1595, 1446, 1260, 761, 691; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{30}H_{26}ClN_2O_2$ 481.1683; Found 481.1680.

1-((4-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-(m-tolyl)furan-2-yl)-5-(m-tolyl)-1,5-dihydro-2H-pyrrol-2-one (3s)



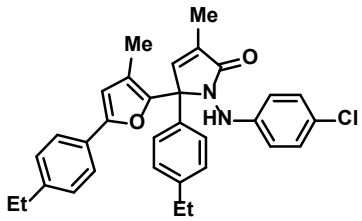
white solid (28.9 mg, 60% yield); mp: 196-198 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.31 (d, J = 7.6 Hz, 2H), 7.28 (s, 1H), 7.24 (d, J = 7.6 Hz, 2H), 7.15 (d, J = 6.8 Hz, 1H), 7.08 (d, J = 8.8 Hz, 4H), 6.88 (d, J = 8.0 Hz, 2H), 6.34 (d, J = 6.8 Hz, 2H), 6.31 (s, 1H), 2.37 (s, 3H), 2.33 (s, 3H), 2.06 (s, 3H), 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): δ 170.6, 152.4, 145.5, 144.3, 143.9, 139.1, 138.4, 137.2, 130.3, 129.3, 129.1, 128.7, 128.6, 128.5, 127.1, 125.1, 124.4, 124.0, 121.1, 114.2, 110.0, 71.1, 21.63, 21.58, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3263, 2910, 1704, 1557, 1505, 1455, 749, 674; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{30}H_{26}ClN_2O_2$ 481.1683; Found 481.1680.

1-((4-chlorophenyl)amino)-3-methyl-5-(3-methyl-5-(o-tolyl)furan-2-yl)-5-(o-tolyl)-1,5-dihydro-2H-pyrrol-2-one (3t)



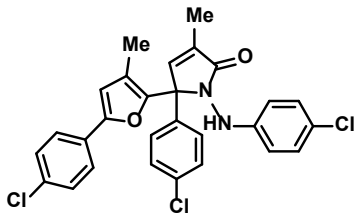
white solid (28.0 mg, 58% yield); mp: 130-132 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.71 (d, J = 7.6 Hz, 1H), 7.31 (s, 1H), 7.29 (s, 2H), 7.24 (d, J = 4.8 Hz, 2H), 7.22 (s, 1H), 7.19-7.15 (m, 1H), 7.03 (d, J = 8.4 Hz, 2H), 6.69 (s, 1H), 6.56 (d, J = 8.4 Hz, 2H), 6.40 (s, 1H), 5.62 (s, 1H), 2.54 (s, 3H), 2.40 (s, 3H), 2.20 (s, 3H), 1.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 178.7, 151.6, 145.6, 145.0, 143.9, 137.5, 134.5, 131.3, 130.3, 130.2, 130.0, 129.6, 129.4, 129.0, 127.5, 126.9, 126.1, 125.7, 118.2, 114.7, 113.77, 113.75, 111.8, 71.0, 22.12, 22.08, 20.2, 11.1; IR (KBr, *v*, cm^{-1}): 3262, 2921, 1698, 1598, 1490, 1455, 784, 695; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{30}H_{26}ClN_2O_2$ 481.1683; Found 481.1692.

1-((4-chlorophenyl)amino)-5-(4-ethylphenyl)-5-(5-(4-ethylphenyl)-3-methylfuran-2-yl)-3-methyl-1,5-dihydro-2H-pyrrol-2-one (3u)



white solid (33.2 mg, 65% yield); mp: 175-176 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.42 (d, J = 8.0 Hz, 2H), 7.20 (s, 4H), 7.17 (s, 2H), 7.06 (s, 1H), 6.87 (d, J = 8.4 Hz, 2H), 6.31 (s, 2H), 6.29 (s, 1H), 6.23 (s, 1H), 2.70-2.63 (m, 4H), 1.59 (s, 3H), 1.27 (d, J = 7.6 Hz, 3H), 1.23 (d, J = 8.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.4, 145.6, 144.7, 144.1, 144.0, 134.4, 128.63, 128.57, 128.3, 128.0, 126.8, 125.0, 123.9, 114.2, 109.4, 70.9, 28.8, 28.5, 15.7, 15.5, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3272, 2941, 1715, 1599, 1490, 1456,818, 761; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{32}H_{30}ClN_2O_2$ 509.1996; Found 509.2003.

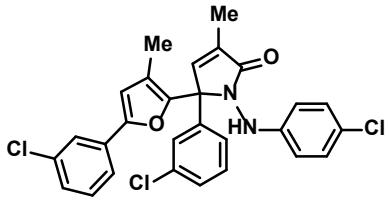
5-(4-chlorophenyl)-5-(5-(4-chlorophenyl)-3-methylfuran-2-yl)-1-((4 chlorophenyl)amino)-3-methyl-1,5-dihydro-2H-pyrrol-2-one (3v)



white solid (39.2 mg, 75% yield); mp: 137-138 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.40 (d, J = 8.0 Hz, 2H), 7.34-7.31 (m, 4H), 7.24 (s, 1H), 7.20-7.17 (m, 1H), 7.03 (s, 1H), 6.87 (d, J = 8.0 Hz,

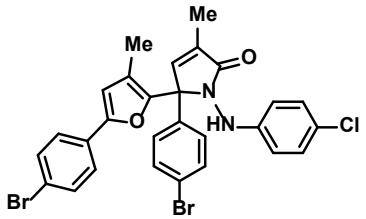
2H), 6.36 (s, 2H), 6.27 (d, J = 8.0 Hz, 2H), 2.06 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.5, 151.3, 145.3, 144.3, 135.8, 134.6, 133.5, 129.4, 129.2, 129.0, 128.9, 128.7, 128.3, 125.4, 125.0, 124.9, 114.9, 110.5, 70.5, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3263, 2965, 1699, 1597, 1491, 1417,817, 763; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{20}Cl_3N_2O_2$ 521.0590; Found 521.0599.

5-(3-chlorophenyl)-5-(5-(3-chlorophenyl)-3-methylfuran-2-yl)-1-((4-chlorophenyl)amino)-3-methyl-1,5-dihydro-2H-pyrrol-2-one (3w)



white solid (33.9 mg, 65% yield); mp: 165-167 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.36 (s, 1H), 7.33 (d, J = 6.8 Hz, 2H), 7.29 (d, J = 7.2 Hz, 2H), 7.24 (d, J = 8.0 Hz, 1H), 7.18 (d, J = 6.4 Hz, 1H), 7.04 (s, 1H), 6.88 (d, J = 8.0 Hz, 2H), 6.39 (s, 2H), 6.29 (d, J = 8.4 Hz, 2H), 2.08 (s, 3H), 1.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.4, 151.0, 145.1, 144.4, 142.9, 139.4, 135.2, 134.8, 132.1, 131.8, 130.4, 130.0, 128.7, 128.6, 127.7, 126.8, 125.4, 125.0, 123.7, 122.8, 121.9, 114.1, 111.1, 70.5, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3259, 2913, 1700, 1565, 1490, 1404,816, 743; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{20}Cl_3N_2O_2$ 521.0590; Found 521.0590.

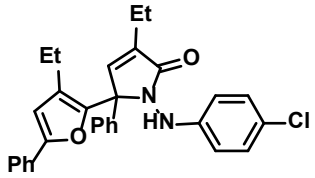
5-(4-bromophenyl)-5-(5-(4-bromophenyl)-3-methylfuran-2-yl)-1-((4-chlorophenyl)amino)-3-methyl-1,5-dihydro-2H-pyrrol-2-one (3x)



white solid (44.7 mg, 73% yield); mp: 176-178 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 7.6 Hz, 2H), 7.38 (s, 1H), 7.36-7.34 (m, 4H), 7.33 (s, 2H), 7.29 (s, 1H), 7.08 (s, 1H), 6.87 (d, J = 8.4 Hz, 2H), 6.37 (s, 1H), 6.30 (d, J = 8.4 Hz, 3H), 2.06 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.2, 144.5, 144.4, 143.7, 137.3, 130.4, 129.2, 128.8, 128.63, 128.57, 127.7, 126.9, 125.2, 123.8, 123.8, 114.2, 110.1, 71.1, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3258, 2910, 1703, 1594,

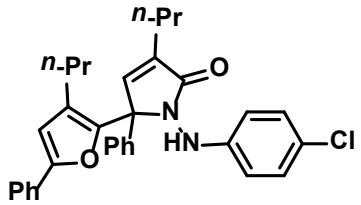
1490, 1404,783, 769; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{28}H_{20}Br_2ClN_2O_2$ 610.9560; Found 610.9568.

1-((4-chlorophenyl)amino)-3-ethyl-5-(3-ethyl-5-phenylfuran-2-yl)-5-phenyl-1,5-dihydro-2H-pyrrol-2-one (3aa)



white solid (29.0 mg, 62% yield); mp: 188-190 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 7.6 Hz, 2H), 7.38-7.34 (m, 5H), 7.29 (s, 2H), 7.29 (s, 1H), 7.02 (s, 1H), 6.85 (d, J = 8.4 Hz, 2H), 6.49 (s, 1H), 6.37 (s, 1H), 6.27 (d, J = 8.4 Hz, 2H), 2.51-2.42 (m, 2H), 2.00-1.93 (m, 2H), 1.28-1.24 (m, 3H), 0.88-0.85 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.4, 152.4, 145.6, 143.8, 142.2, 137.6, 130.4, 129.1, 128.8, 128.6, 128.5, 127.7, 126.8, 125.1, 123.8, 123.8, 114.2, 107.9, 71.2, 19.3, 18.5, 13.9, 11.7; IR (KBr, *v*, cm^{-1}): 3259, 2912, 1698, 1597, 1490, 1448,760, 692; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{30}H_{26}ClN_2O_2$ 481.1683; Found 481.1686.

1-((4-chlorophenyl)amino)-5-phenyl-5-(5-phenyl-3-propylfuran-2-yl)-3-propyl-1,5-dihydro-2H-pyrrol-2-one (3bb)



white solid (33.1 mg, 60% yield); mp: 204-205 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.48 (d, J = 7.6 Hz, 2H), 7.36 (d, J = 6.4 Hz, 5H), 7.33 (s, 2H), 7.27 (d, J = 5.4 Hz, 1H), 7.02 (s, 1H), 6.87 (d, J = 7.6 Hz, 2H), 6.46 (s, 1H), 6.29 (d, J = 8.0 Hz, 2H), 6.20 (s, 1H), 2.46-2.36 (m, 2H), 1.92 (s, 2H), 1.74-1.65 (m, 2H), 1.37-1.27 (m, 2H), 1.04-1.00 (mz, 3H), 0.73-0.69 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.4, 152.3, 145.6, 144.1, 142.8, 137.5, 135.7, 130.3, 129.0, 128.7, 128.6, 128.5, 127.6, 127.3, 126.9, 125.1, 123.7, 114.2, 108.2, 71.1, 27.8, 27.2, 22.7, 20.6, 14.0, 13.8; IR (KBr, *v*, cm^{-1}): 3271, 2965, 1668, 1602, 1495, 1448,748, 690; HRMS (ESI -TOF) *m/z*: [M-H]$^-$Calcd for $C_{32}H_{30}ClN_2O_2$ 509.1996; Found 509.1999.

General Procedure for the Synthesis of Products 5a-5i

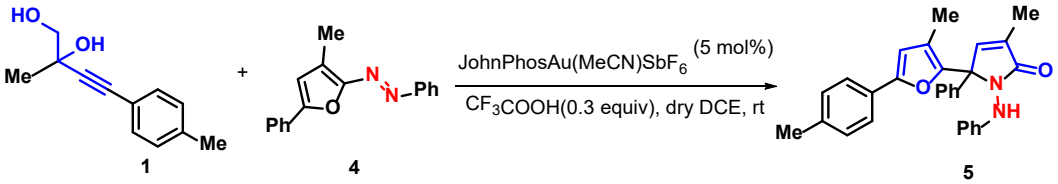
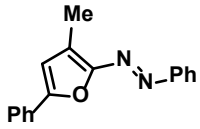


Figure S13. Synthesis of Compounds **5**

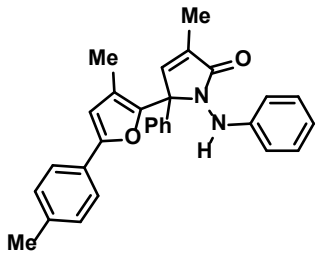
To a 10-mL pressure tube under air conditions, 2-methyl-4-(p-tolyl)but-3-yne-1,2-diol (**1b**, 0.1 mmol, 2 equiv, 38.0 mg), (*E*)-1-(3-methyl-5-phenylfuran-2-yl)-2-phenyldiazene (**4**, 0.1 mmol, 1 equiv, 26.2 mg), CF_3COOH (0.03 mmol, 0.3 equiv, 3.4 mg), JohnPhosAu(MeCN)SbF_6 (5.0 mol%, 3.86 mg), dry 1,2-dichloroethane (2.0 mL) were successively added. The mixture was stirred at room temperature for about 12 hours. After the reaction was completed (indicated by TLC, petroleum ether : ethyl acetate = 5:1), the reaction mixture was concentrated by vacuum distillation and was purified by flash column chromatography to afford the desired pure product (**5a**, 28.2 mg, 65% yield) as white solid.

(E)-1-(3-methyl-5-phenylfuran-2-yl)-2-phenyldiazene (4)



orange solid (15.7 mg, 60% yield); mp: 98-99 °C; ^{1}H NMR (400 MHz, DMSO-d_6) (δ, ppm): 7.87-7.84 (m, 4H), 7.58-7.48 (m, 5H), 7.46-7.42 (m, 1H), 7.32 (s, 1H), 2.47 (s, 3H), ^{13}C NMR (100 MHz, DMSO-d_6) (δ, ppm): 155.4, 154.0, 153.6, 130.8, 130.0, 129.9, 129.7, 129.3, 125.3, 122.5, 113.1, 11.0. IR (KBr, *v*, cm^{-1}): 2913, 1615, 1565, 1490, 1404, 761, 693; HRMS (ESI -TOF) *m/z*: $[M+H]^+$ Calcd for $C_{17}H_{13}N_2O$ 263.1184; Found 263.1191.

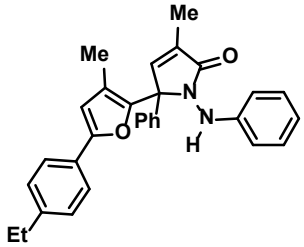
3-methyl-5-(3-methyl-5-(p-tolyl)furan-2-yl)-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5a)



white solid (28.2 mg, 65% yield); mp:189-191 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.43 (d, J = 8.0 Hz, 2H), 7.36 (s, 5H), 7.18 (d, J = 8.0 Hz, 2H), 7.09 (s, 1H), 6.97-6.93 (m, 2H), 6.70-6.67 (m,

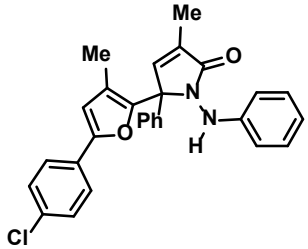
1H), 6.41 (d, J = 8.0 Hz, 2H), 6.31 (s, 2H), 2.39 (s, 3H), 2.09 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.3, 146.8, 144.2, 143.7, 137.6, 137.5, 131.5, 129.4, 129.1, 128.7, 128.4, 127.9, 127.0, 123.8, 122.4, 120.4, 113.0, 109.4, 71.1, 21.4, 11.6, 11.3; IR (KBr, *v*, cm^{-1}): 3266, 2909, 1698, 1605, 1486, 1447,740, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{29}H_{25}N_2O_2$ 433.1916; Found 433.1922.

5-(5-(4-ethylphenyl)-3-methylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5b)



white solid (28.2 mg, 63% yield); mp: 199-201 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.44 (d, J = 8.0 Hz, 2H), 7.35 (s, 5H), 7.20 (d, J = 8.0 Hz, 2H), 7.07 (s, 1H), 6.97-6.93 (m, 2H), 6.70-6.66 (m, 1H), 6.40 (d, J = 8.0 Hz, 2H), 6.30 (s, 1H), 6.13 (s, 1H), 2.67-2.64 (m, 2H), 2.06 (s, 3H), 1.58 (s, 3H), 1.28-1.24 (t, J = 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.3, 146.8, 144.2, 143.9, 137.6, 129.1, 128.7, 128.4, 128.2, 128.1, 127.0, 123.9, 120.5, 113.0, 109.4, 71.1, 28.8, 15.6, 11.6, 11.2; IR (KBr, *v*, cm^{-1}): 3266, 2945, 1698, 1603, 1497, 1398,747, 690; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{30}H_{27}N_2O_2$ 447.2073; Found 447.2081.

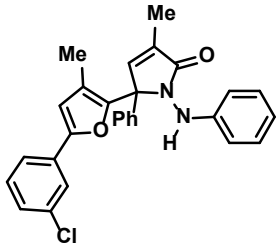
5-(5-(4-chlorophenyl)-3-methylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5c)



white solid (34.1 mg, 75% yield); mp:180-181 °C; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.40 (d, J = 8.0 Hz, 2H), 7.36 (d, J = 6.4 Hz, 2H), 7.31 (d, J = 8.0 Hz, 5H), 7.06 (s, 1H), 6.95-6.92 (m, 2H), 6.69-6.66 (m, 1H), 6.39 (d, J = 8.0 Hz, 2H), 6.34 (s, 1H), 6.19 (s, 1H), 2.07 (s, 3H), 1.61 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 151.1, 146.7, 145.0, 143.4, 137.4, 133.2, 129.2, 129.0,

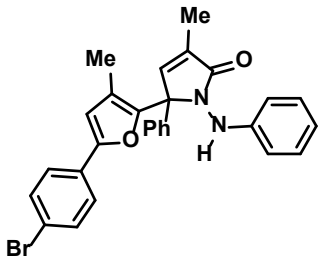
128.9, 128.7, 128.5, 126.9, 125.0, 123.8, 122.5, 120.5, 113.0, 110.5, 71.0, 11.6, 11.3;IR (KBr, *v*, cm^{-1}): 3270, 2920, 1699, 1595, 1496, 1456,746, 693; HRMS (ESI -TOF) *m/z*: $[M-H]^-$ Calcd for $C_{28}H_{22}N_2O_2$ 453.1370; Found 453.1375.

5-(5-(3-chlorophenyl)-3-methylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5d)



white solid (30.9 mg, 68% yield); mp:205-206 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm):δ 7.43 (s, 1H), 7.38-7.34 (m, 4H), 7.30 (d, J = 8.0 Hz, 3H), 7.25-7.20 (m, 1H), 7.06 (s, 1H), 6.96-6.93 (m, 2H), 6.70-6.66(m, 1H), 6.41-6.37 (m, 3H), 6.10 (s, 1H), 2.07 (s, 3H), 1.61 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.8, 152.1, 145.6, 144.5, 143.9, 137.3, 131.4, 130.4, 129.2, 128.81, 128.79, 128.6, 128.5, 127.7, 126.9, 125.0, 123.8, 114.1, 110.1, 71.1, 11.6, 11.3; ;IR (KBr, *v*, cm^{-1}): 3271, 2922, 1699, 1601, 1496, 1447,747, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{28}H_{22}N_2O_2$ 453.1370; Found 453.1379.

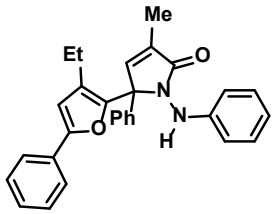
5-(5-(4-bromophenyl)-3-methylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5e)



white solid (35.9 mg, 72% yield); mp: 203-204 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.57 (d, J = 7.6 Hz, 2H), 7.43 (s, 2H), 7.41 (s, 5H), 7.13 (s, 1H), 7.01-6.98 (m, 2H), 6.75-6.71 (m, 1H), 6.46 (d, J = 8.0 Hz, 2H), 6.41 (s, 1H), 6.19 (s, 1H), 2.12 (s, 3H), 1.64 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 169.7, 151.1, 145.7, 143.6, 142.5, 136.5, 130.8, 130.6, 129.5, 128.1, 127.73, 127.68, 127.4, 126.6, 125.9, 122.8, 119.5, 112.0, 109.0, 70.1, 10.6, 10.2; IR (KBr, *v*, cm^{-1}): 3269, 2965, 1699, 1602,

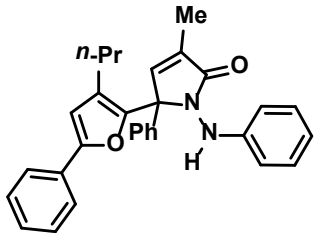
1496, 1448,748, 692; HRMS (ESI -TOF) *m/z*: [M-H]$^-$Calcd for $C_{28}H_{22}BrN_2O_2$ 497.0865; Found 497.0873.

5-(3-ethyl-5-phenylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5f)



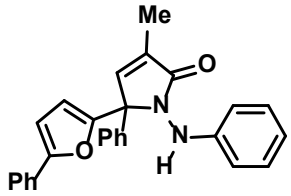
white solid (26.5 mg, 61% yield); mp:198-200 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.55 (d, J = 7.6 Hz, 2H), 7.38 (d, J = 8.4 Hz, 2H), 7.36 (s, 5H), 7.29 (s, 1H), 7.08 (s, 1H), 6.96-6.92 (m, 2H), 6.69-6.66 (m, 1H), 6.48 (s, 1H), 6.40 (d, J = 8.0 Hz, 2H), 6.29 (s, 1H), 2.08 (s, 3H), 2.01-1.94 (m, 2H), 0.88-0.88 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 169.7, 151.4, 145.8, 142.9, 142.6, 136.8, 129.5, 128.1, 128.0, 127.7, 127.6, 127.4, 126.6, 125.8, 122.8, 119.4, 112.0, 106.9, 70.1, 17.5, 12.6, 10.6; IR (KBr, *v*, cm^{-1}): 3114, 2925, 1710, 1652, 1595, 1493,762, 693; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{28}H_{25}N_2O_2$ 433.1916; Found 433.1923.

3-methyl-5-phenyl-5-(5-phenyl-3-propylfuran-2-yl)-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5g)



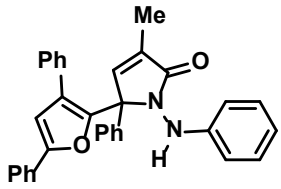
white solid (26.9 mg, 60% yield); mp:199-201 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.51 (d, J = 7.6 Hz, 2H), 7.36 (s, 5H), 7.34 (s, 2H), 7.28 (s, 1H), 7.08 (s, 1H), 6.96-6.92 (m, 2H), 6.70-6.66 (m, 1H), 6.46 (s, 1H), 6.41 (d, J = 8.0 Hz, 2H), 6.16 (s, 1H), 2.08 (s, 3H), 1.96-1.92 (m, 2H), 1.37-1.29 (m, 6.9 Hz, 2H), 0.76-0.70 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.7, 152.3, 146.7, 144.3, 143.4, 137.6, 131.6, 130.4, 129.0, 128.7, 128.6, 128.4, 127.5, 127.2, 127.0, 123.8, 120.4, 113.0, 108.2, 71.0, 27.2, 22.7, 14.0, 11.6; IR (KBr, *v*, cm^{-1}): 3115, 2925, 1710, 1653, 1595, 1493,780, 692; HRMS (ESI -TOF) *m/z*: [M-H]$^-$ Calcd for $C_{30}H_{27}N_2O_2$ 447.2073; Found. 447.2083.

3-methyl-5-phenyl-1-(phenylamino)-5-(5-phenylfuran-2-yl)-1,5-dihydro-2H-pyrrol-2-one (5h)



white solid (24.4 mg, 60% yield); mp: 202-203 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.42 - 7.34 (m, 5H), 7.316-7.280 (m, 4H), 7.26 - 7.19 (m, 1H), 7.09 (s, 1H), 7.00-6.97 (m, 2H), 7.71-6.67 (m, 1H), 6.56 (d, J = 2.8 Hz, 1H), 6.49 (d, J = 8.0 Hz, 2H), 6.34 (d, J = 2.4 Hz, 1H), 5.95 (s, 1H), 2.09 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 170.9, 154.4, 146.8, 143.1, 137.1, 133.0, 130.3, 129.0, 128.8, 128.7, 128.6, 127.7, 127.4, 124.0, 120.7, 113.3, 112.4, 105.7, 70.4, 11.7; IR (KBr, *v*, cm^{-1}): 3266, 2909, 1669, 1603, 1496, 1354, 747, 690; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{27}H_{21}N_2O_2$ 405.1603; Found 405.1618.

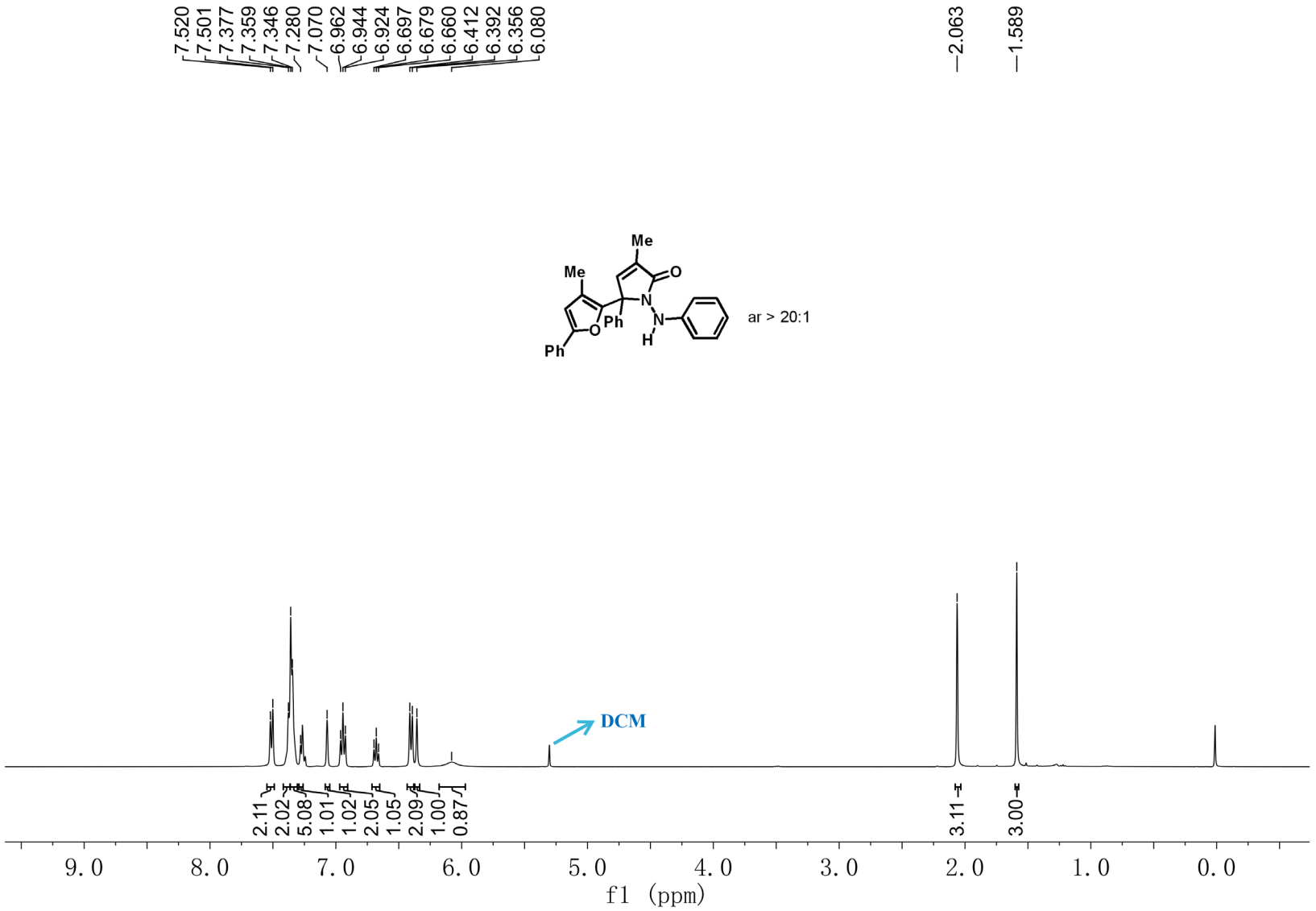
5-(3,5-diphenylfuran-2-yl)-3-methyl-5-phenyl-1-(phenylamino)-1,5-dihydro-2H-pyrrol-2-one (5i)



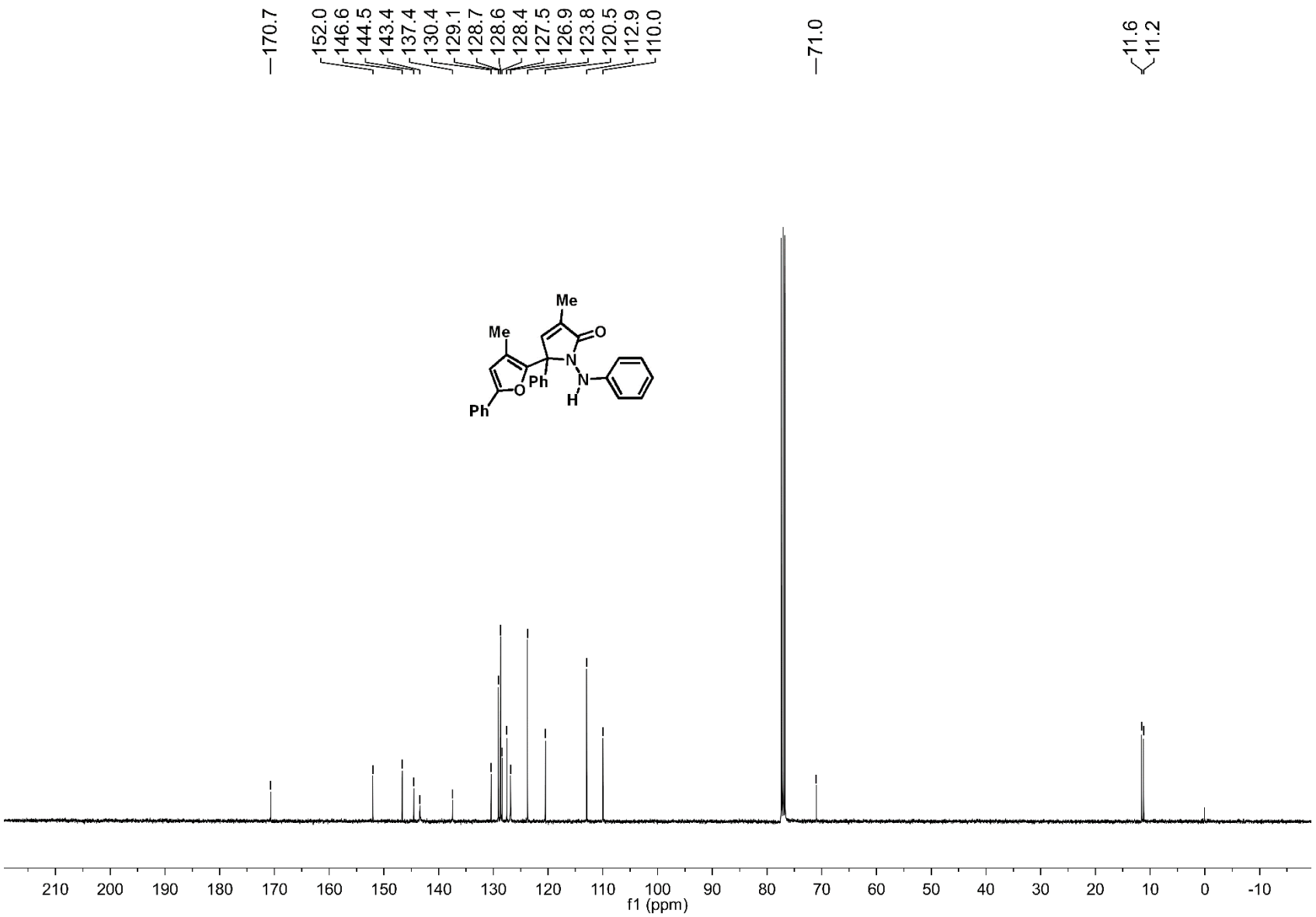
white solid (35.7 mg, 74% yield); mp: 204-205 ºC; ^{1}H NMR (400 MHz, $CDCl_3$) (δ, ppm): 7.42 (d, J = 6.4 Hz, 2H), 7.34 - 7.29 (m, 5H), 7.26 (s, 1H), 7.23 (s, 7H), 6.98-6,94 (m, 2H), 6.88 (s, 1H), 6.68 - 6.65 (m, 2H), 6.42 (s, 2H), 5.81 (s, 1H), 2.08 (s, 1H), 1.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) (δ, ppm): 169.6, 152.1, 145.8, 144.1, 142.5, 136.3, 132.6, 129.12, 129.10, 128.7, 127.84, 127.79, 127.5, 127.1, 127.0, 126.6, 126.5, 123.1, 119.6, 112.4, 70.2, 10.6; IR (KBr, *v*, cm^{-1}): 3270, 2965, 1668, 1602, 1496, 1448,748, 692; HRMS (ESI -TOF) *m/z*: $[M-H]^-$Calcd for $C_{33}H_{25}N_2O_2$ 481.1916; Found 481.1910.

References

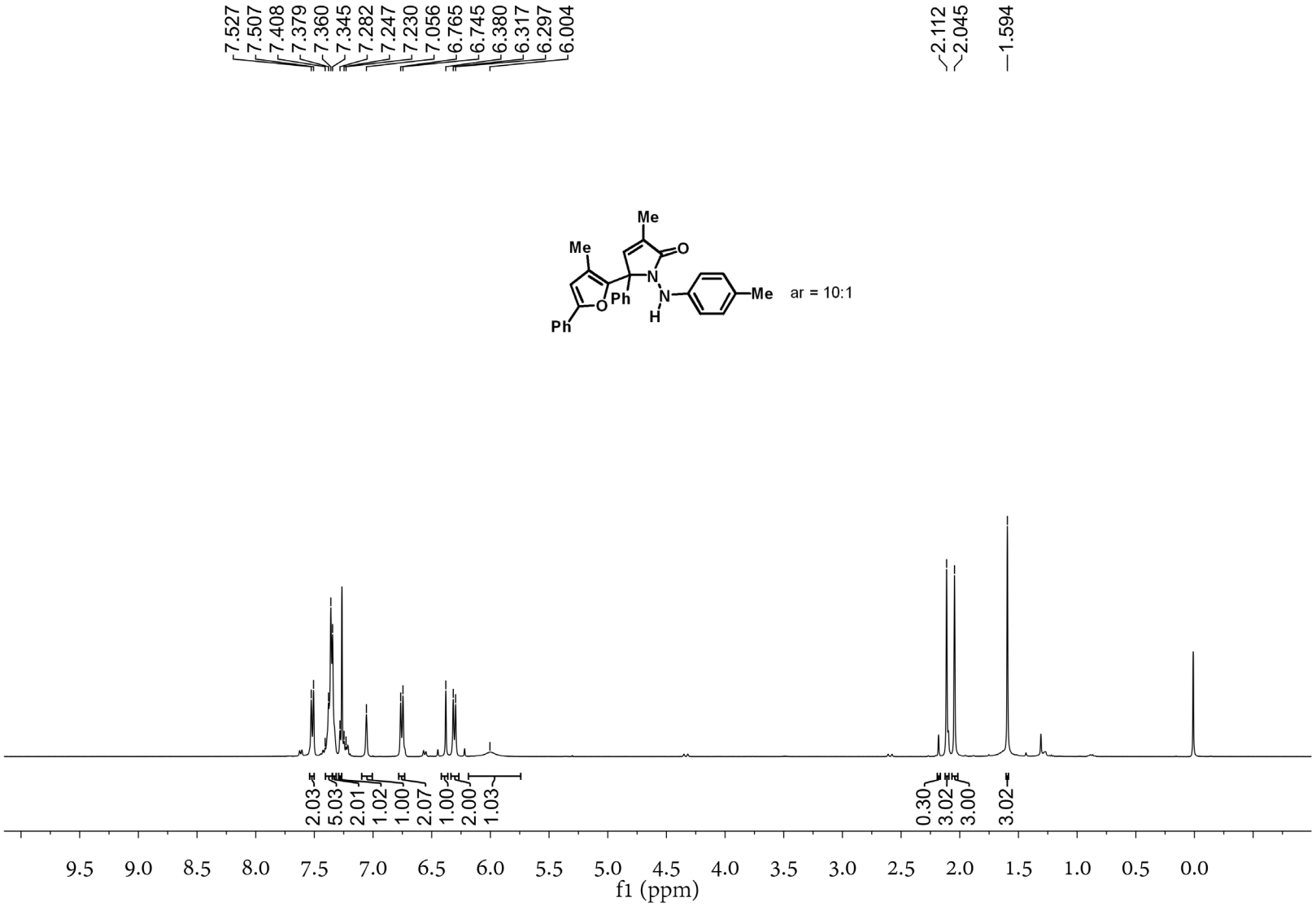
1. Li, X.; Villar-Yanez, A.; Tounzoua, C. N.; Benet-Buchholz, J.; Grignard, B.; Bo, C.; Detrembleur, C.; Kleij, A. W. Cascade Transformation of Carbon Dioxide and Alkyne-1,n-diols into Densely Substituted Cyclic Carbonates. *ACS Catal*. **2022**, *12*, 2854-2860.
2. Gabriele, B.; Veltri, L.; Plastina, P.; Mancuso, R.; Vetere, M. V.; Maltese, V. Copper-Catalyzed Synthesis of Substituted Furans and Pyrroles by Heterocyclodehydration and Tandem Heterocyclodehydration–Hydration of 3-Yne-1,2-diols and 1-Amino-3-yn-2-ol Derivatives. *J. Org. Chem.* **2013**, *78*, 4919-4928.
3. Minkler, S. R. K.; Isley, N. A.; Lippincott, D. J.; Krause, N.; Lipshutz, B. H. Leveraging the Micellar Effect: Gold-Catalyzed Dehydrative Cyclizations in Water at Room Temperature. O*rg. Lett.* **2014**, *16*, 724-726.
4. Spina, R.; Colacino, E.; Martinez, J.; Lamaty, F. Poly(ethylene glycol) as a Reaction Matrix in Platinum- or Gold-Catalyzed Cycloisomerization: A Mechanistic Investigation. *Chem. Eur. J.* **2013** *19*, 3817-3821.
5. Tang, H.-J.; Zhang, X.; Zhang, Y.-F.; Feng, C. Visible-Light-Assisted Gold-Catalyzed Fluoroarylation of Allenoates. *Angew. Chem., Int. Ed.* **2020**, *59*, 5242-5247.
6. Gabriele, B.; Plastina, P.; Vetere, M. V.; Veltri, L.; Mancuso, R.; Salerno, G. A simple and convenient synthesis of substituted furans and pyrroles by $CuCl_2$-catalyzed heterocyclodehydration of 3-yne-1,2-diols and N-Boc- or N-tosyl-1-amino-3-yn-2-ols. *Tetrahedron Lett*. **2010**, *51*, 3565-3567.



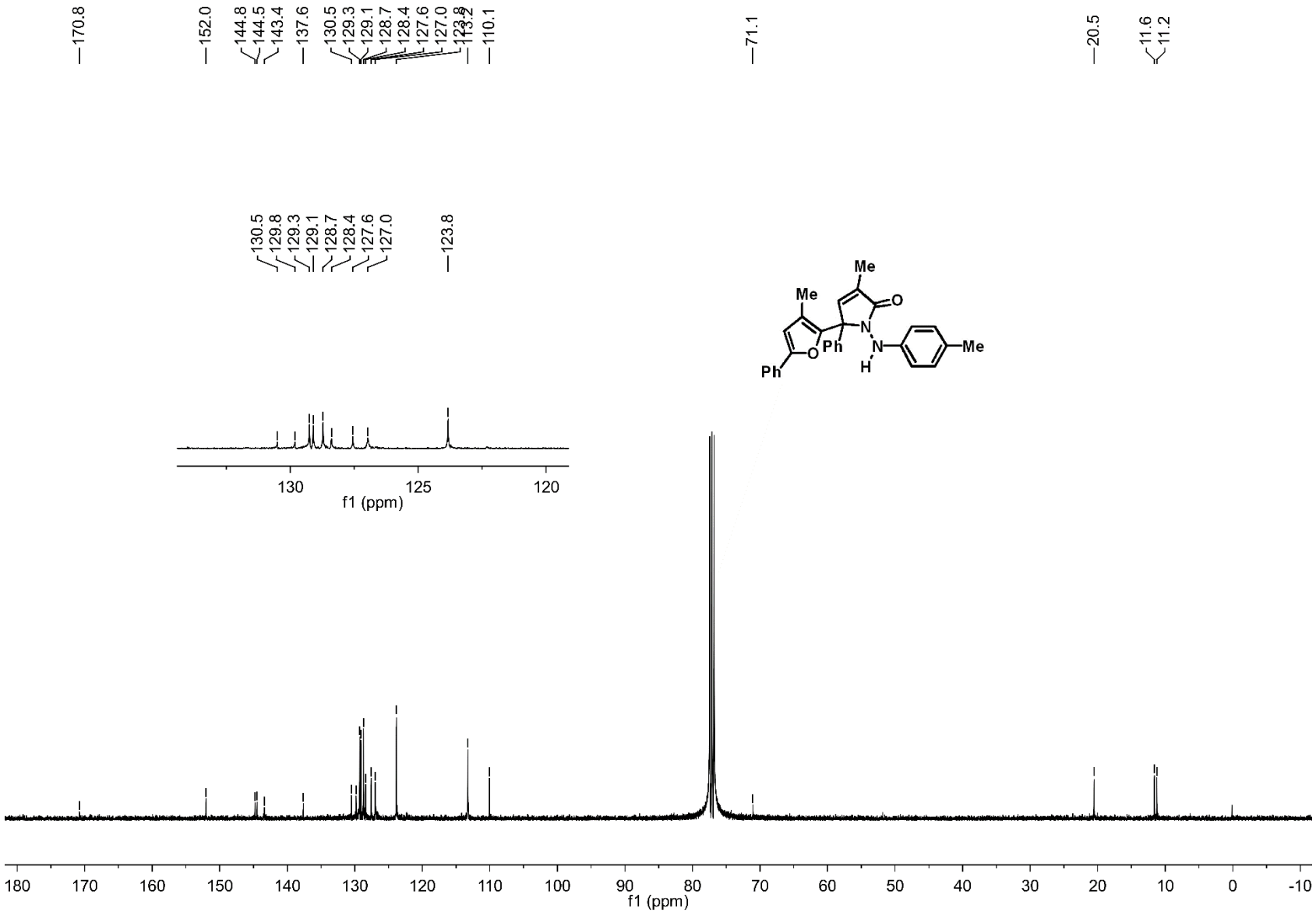
^{1}H NMR Spectrum of Compound **3a**



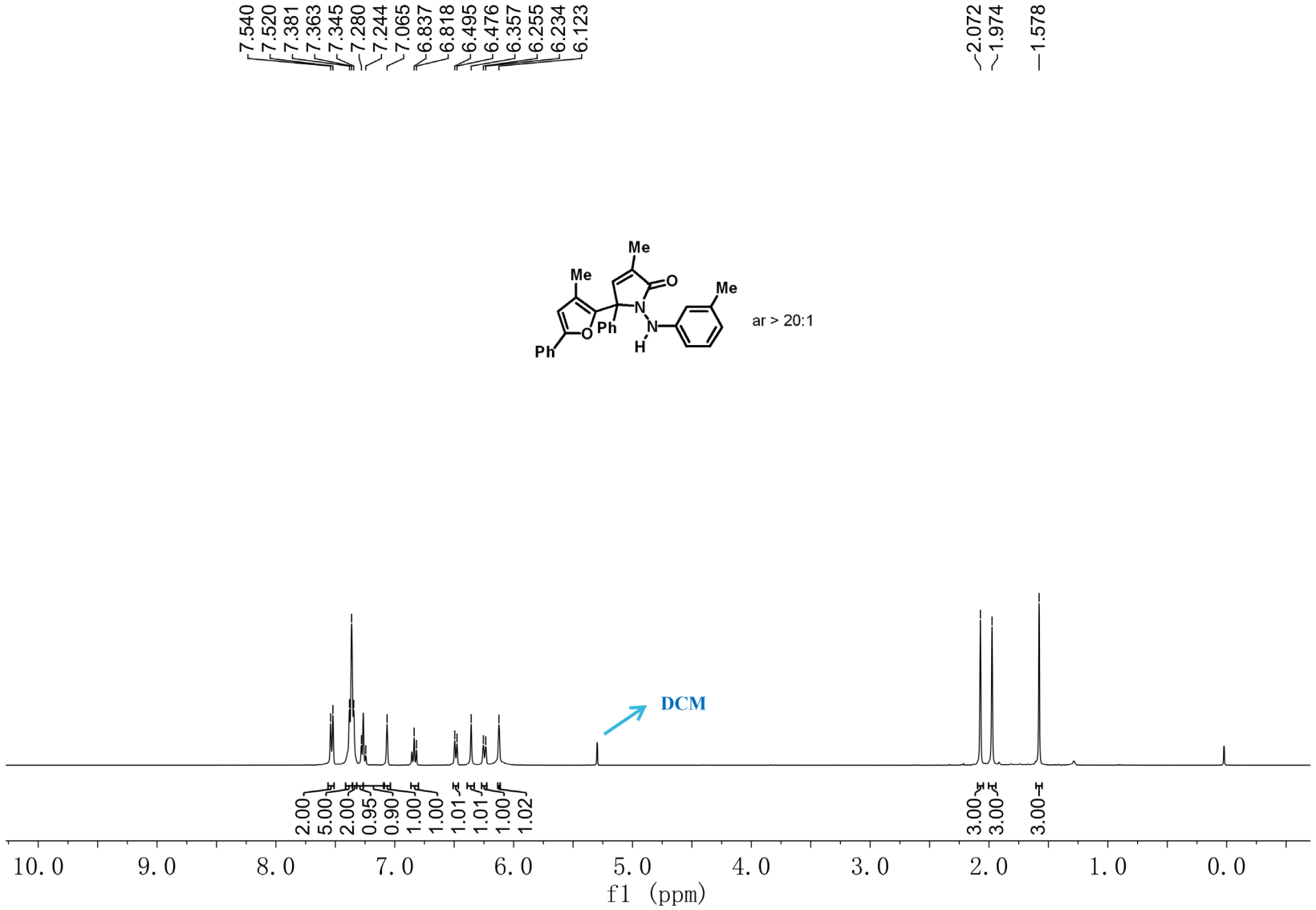
^{13}C NMR Spectrum of Compound **3a**



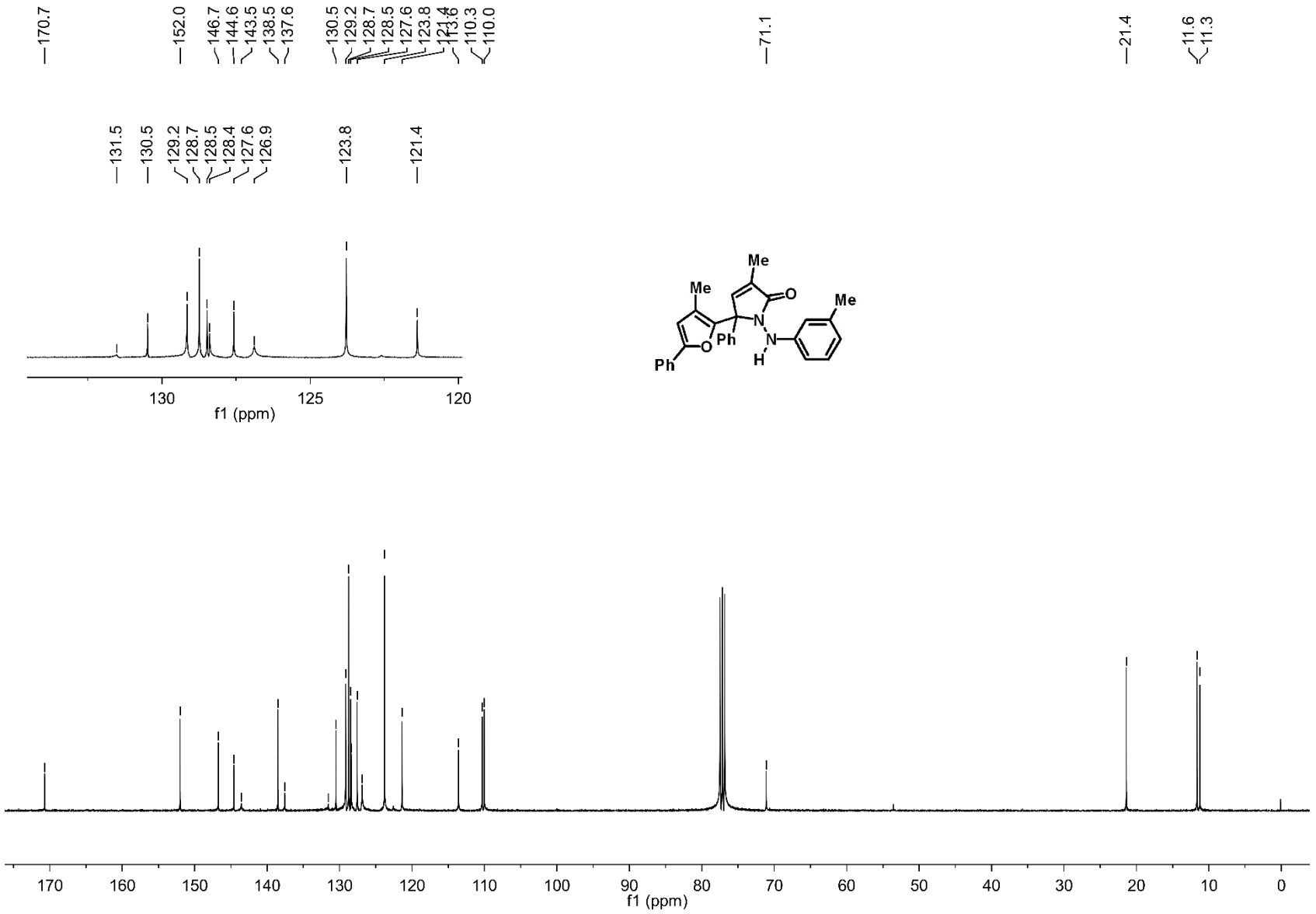
^{1}H NMR Spectrum of Compound **3b**



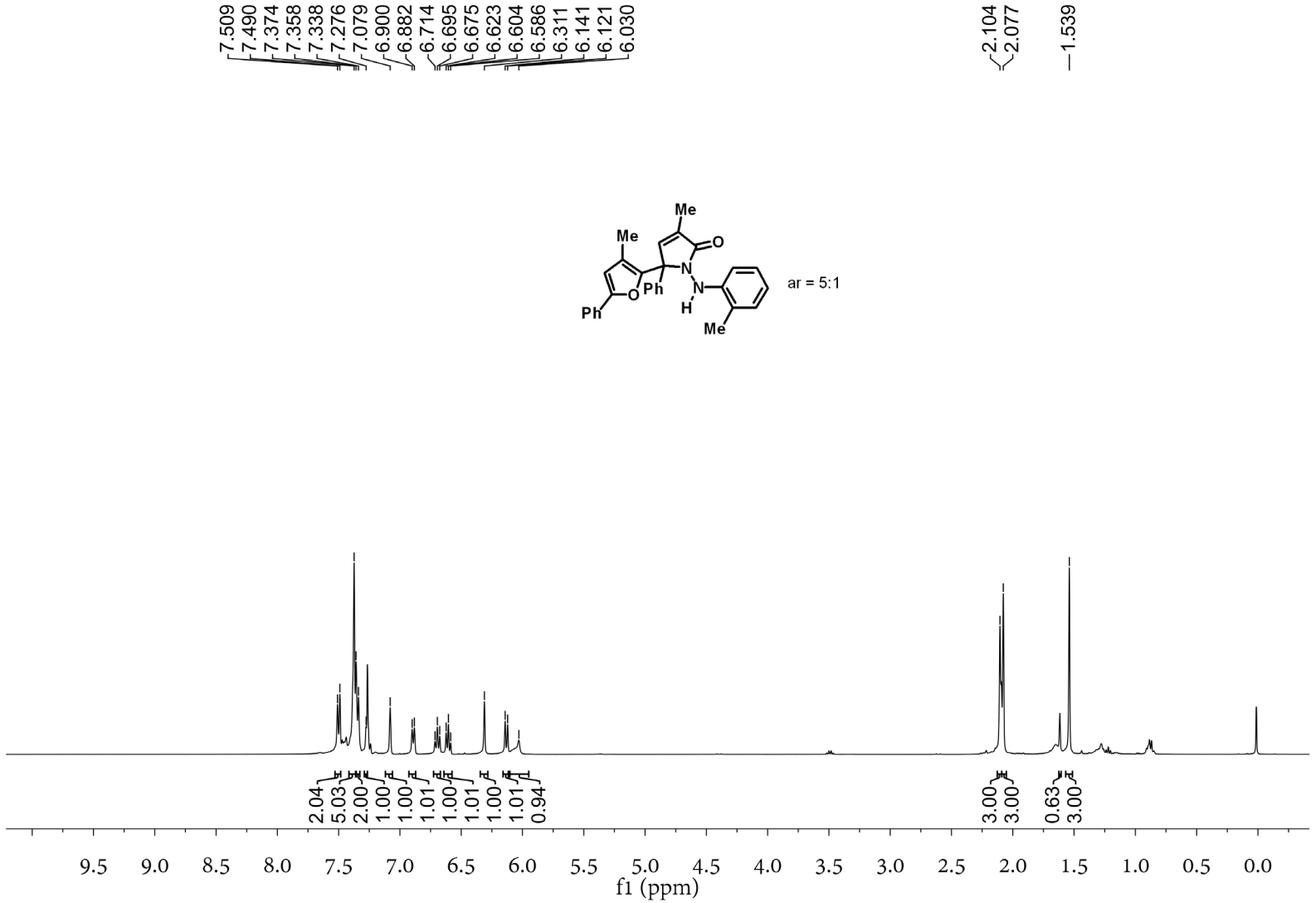
^{13}C NMR Spectrum of Compound **3b**



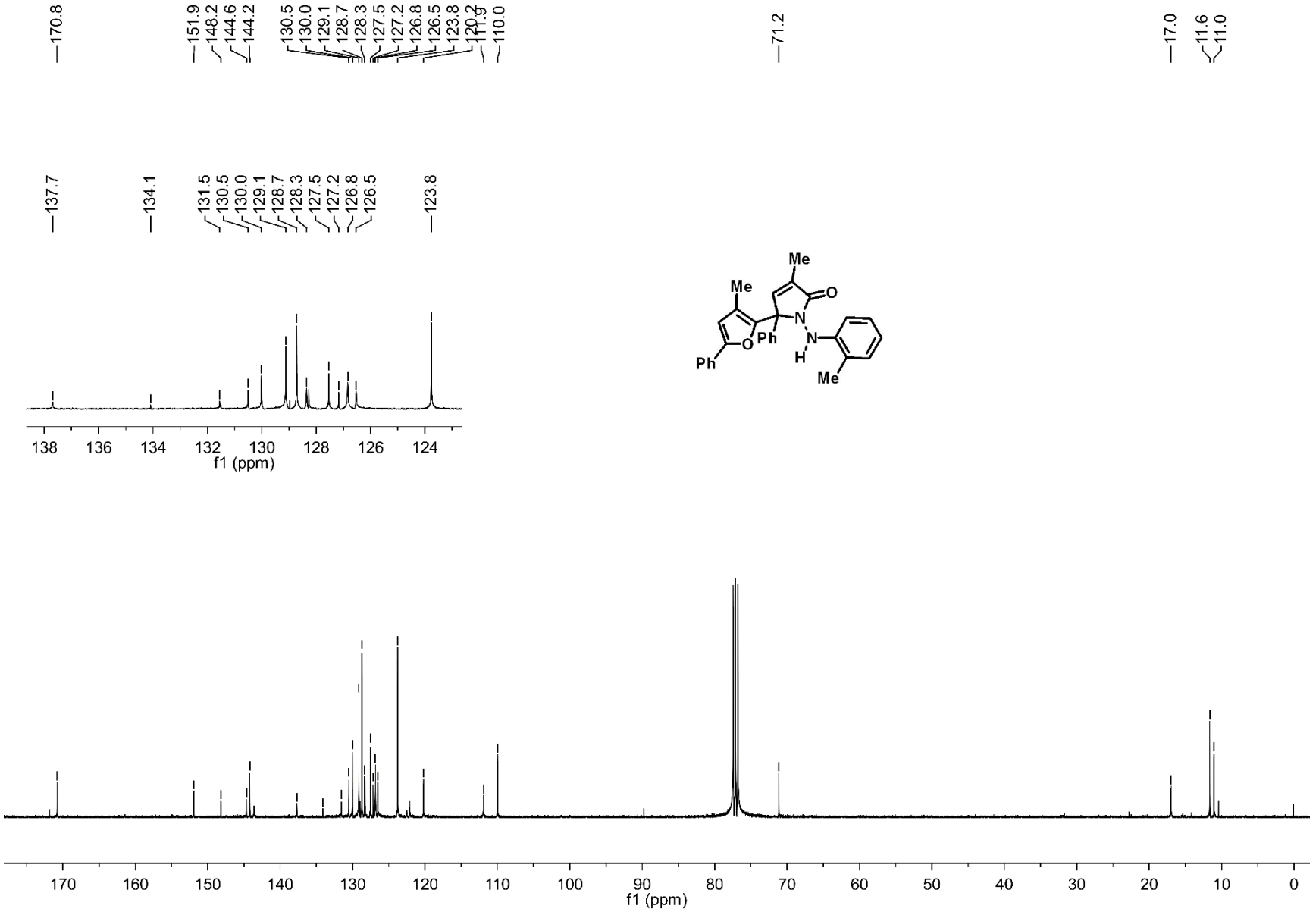
^{1}H NMR Spectrum of Compound **3c**



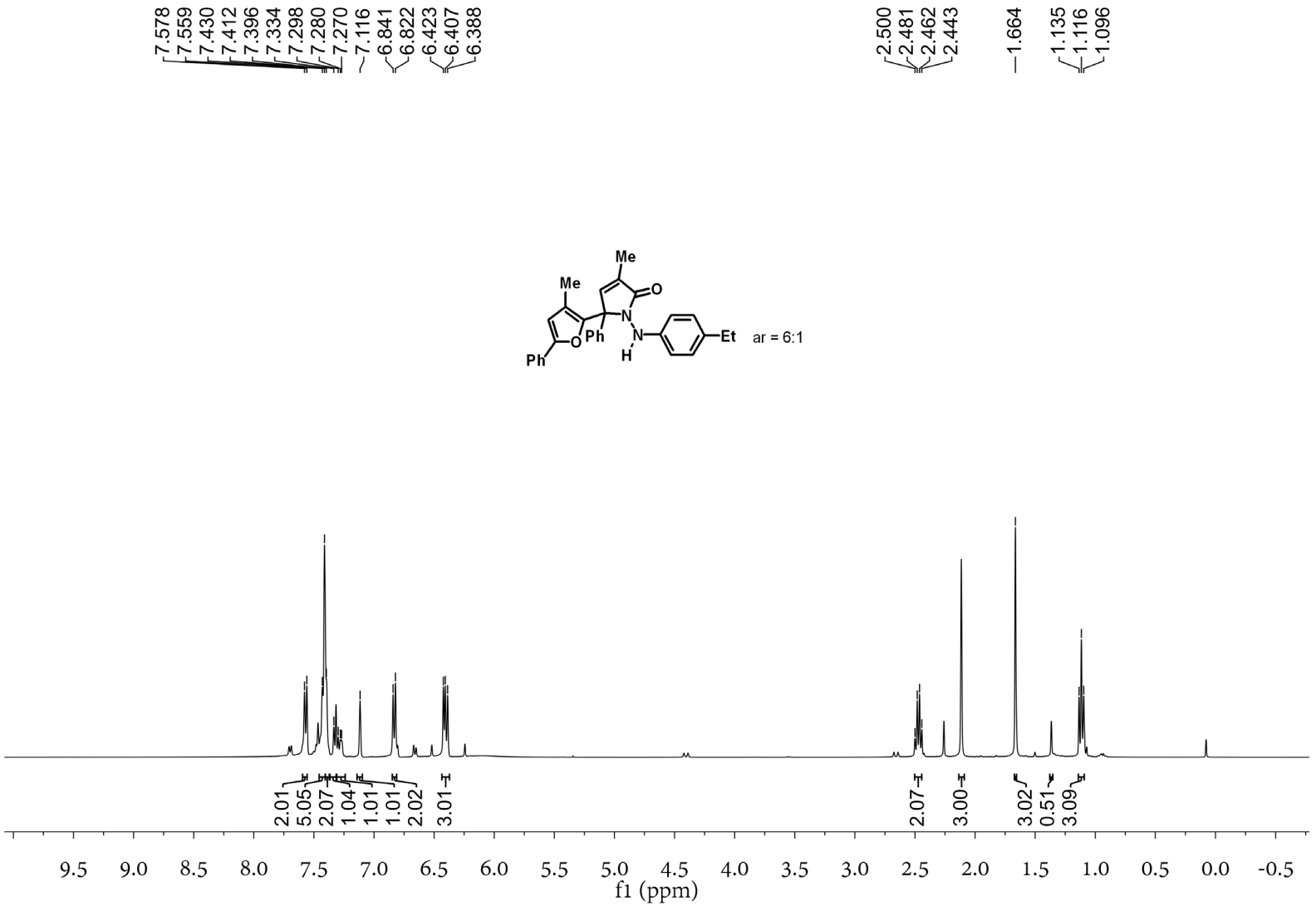
^{13}C NMR Spectrum of Compound **3c**



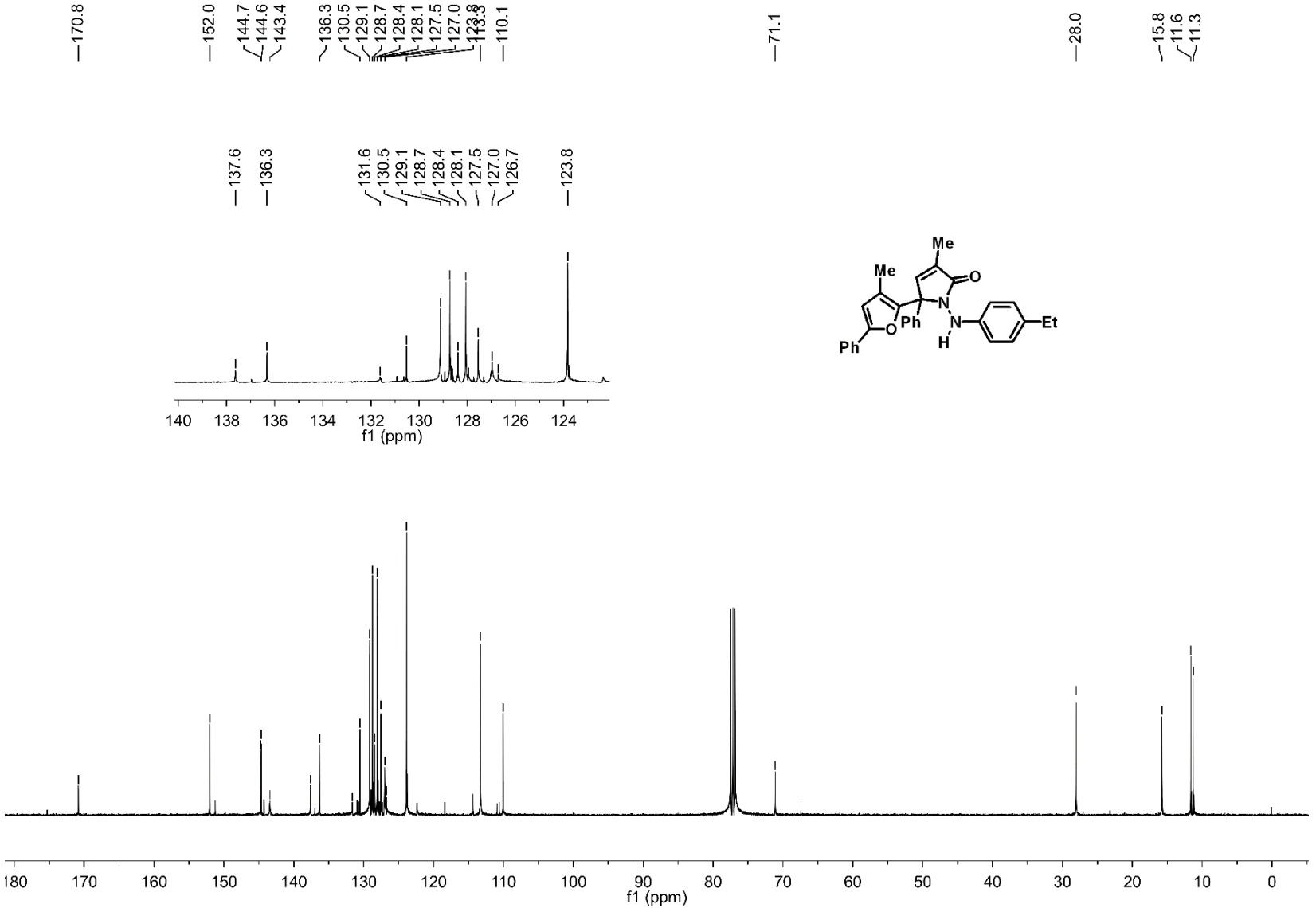
^{1}H NMR Spectrum of Compound **3d**



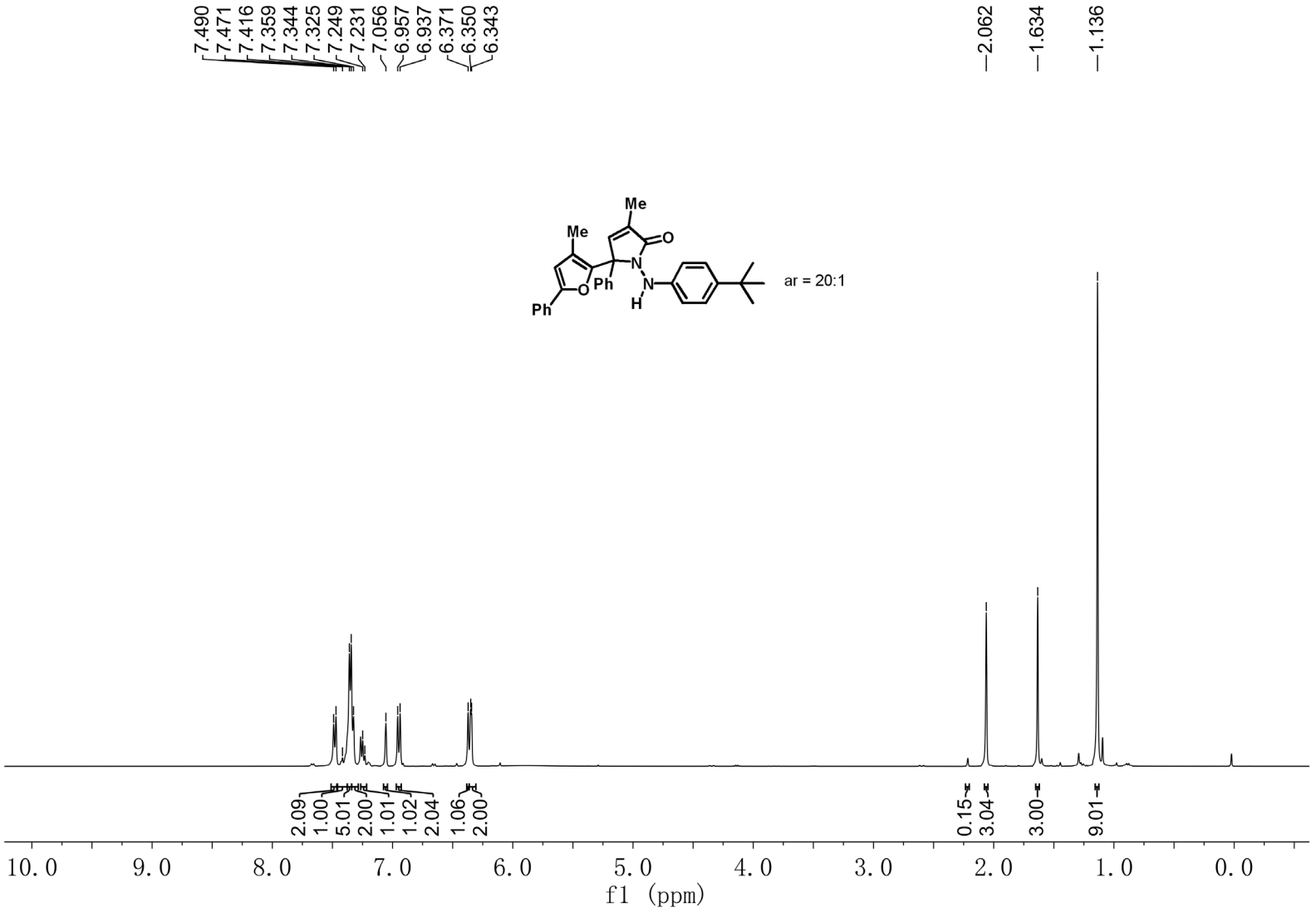
^{13}C NMR Spectrum of Compound **3d**



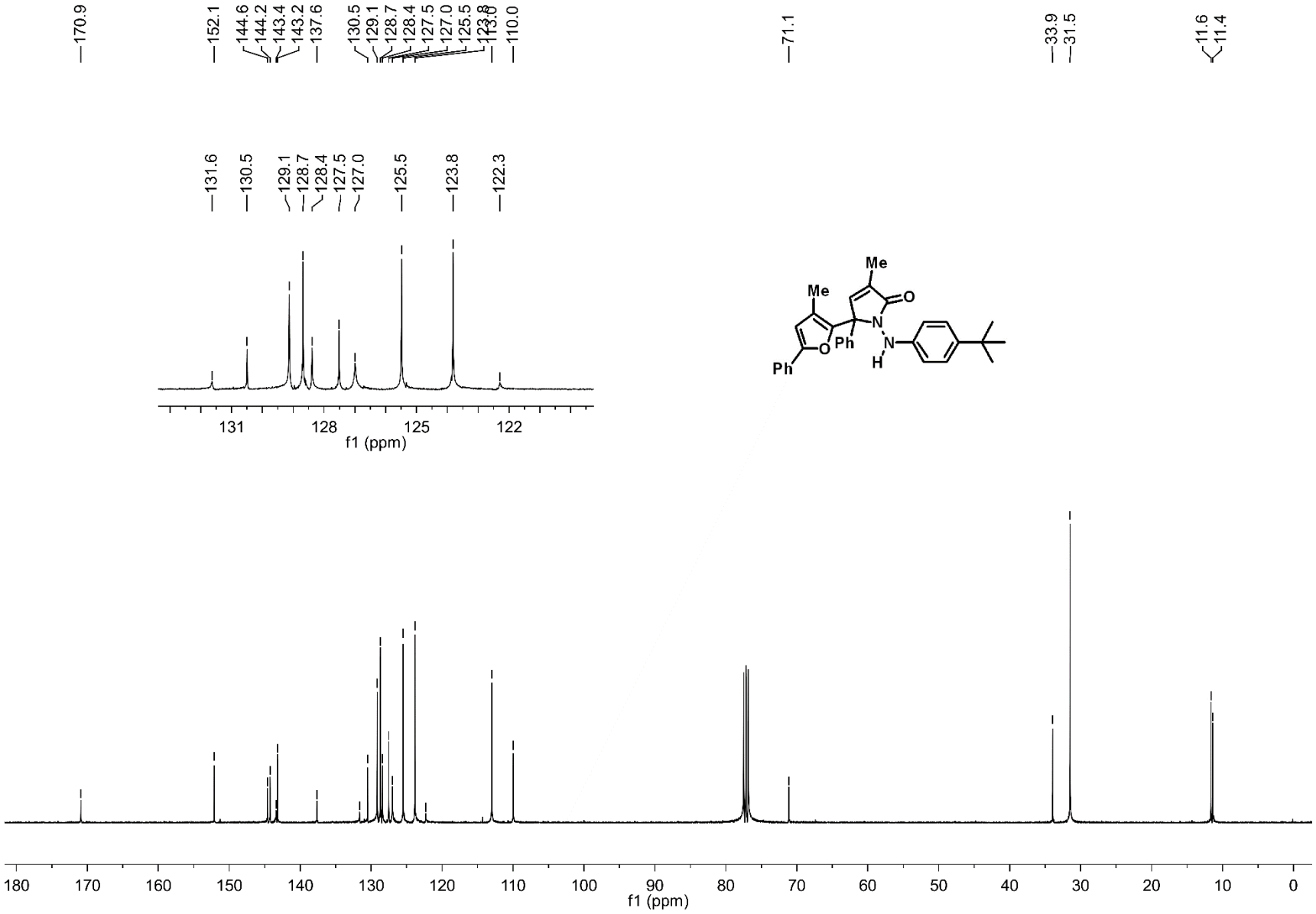
^{1}H NMR Spectrum of Compound **3e**



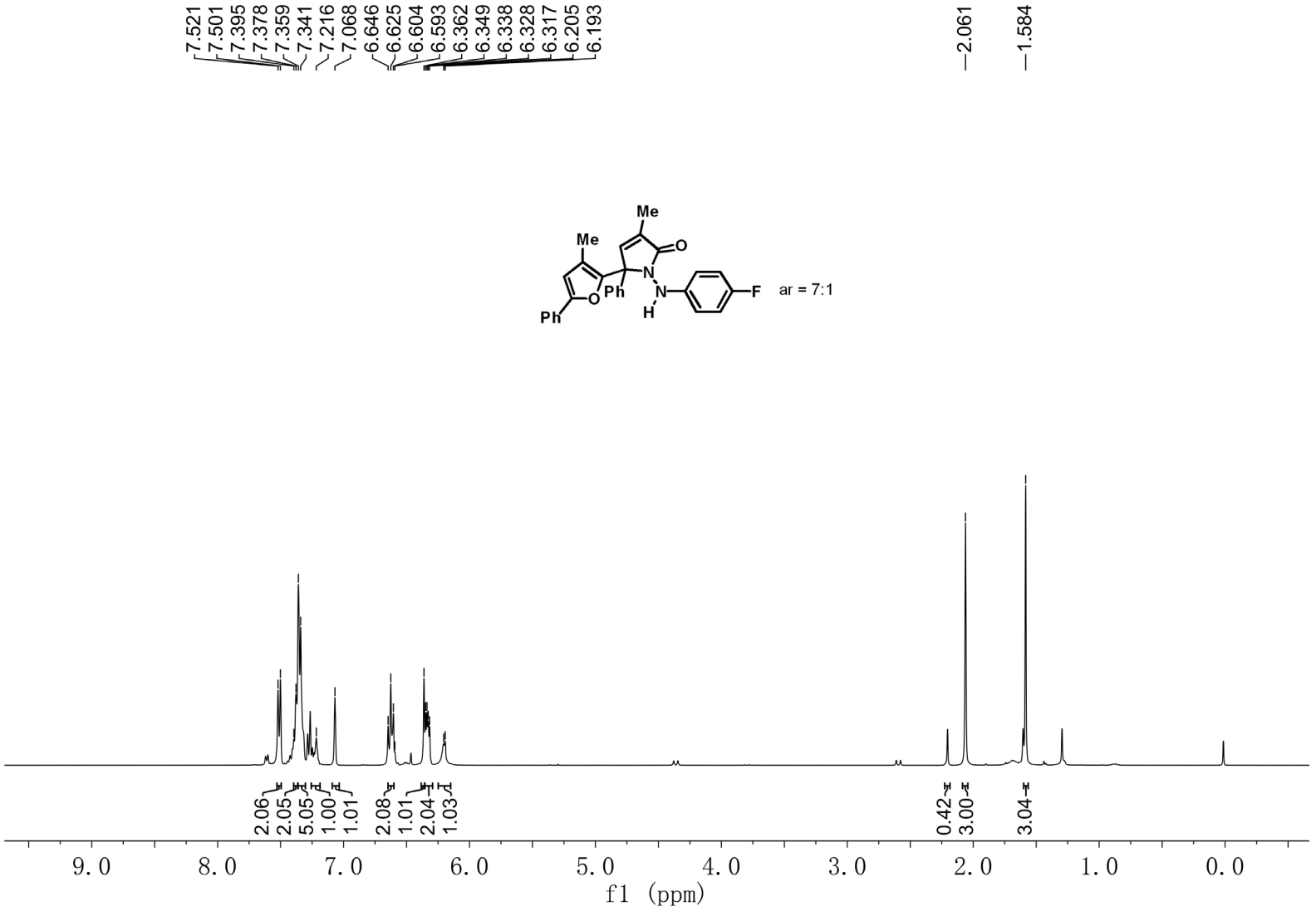
^{13}C NMR Spectrum of Compound **3e**



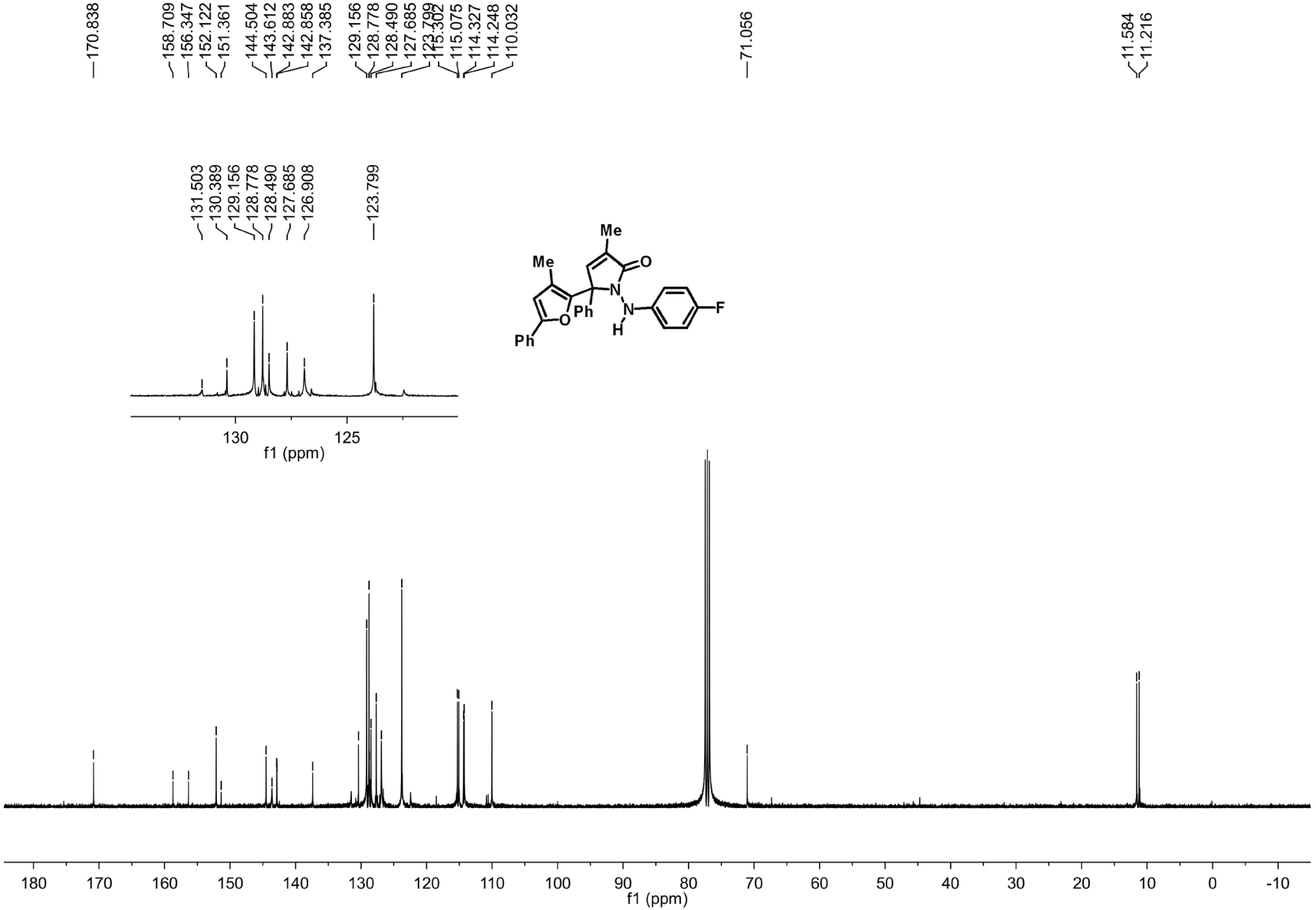
^{1}H NMR Spectrum of Compound **3f**



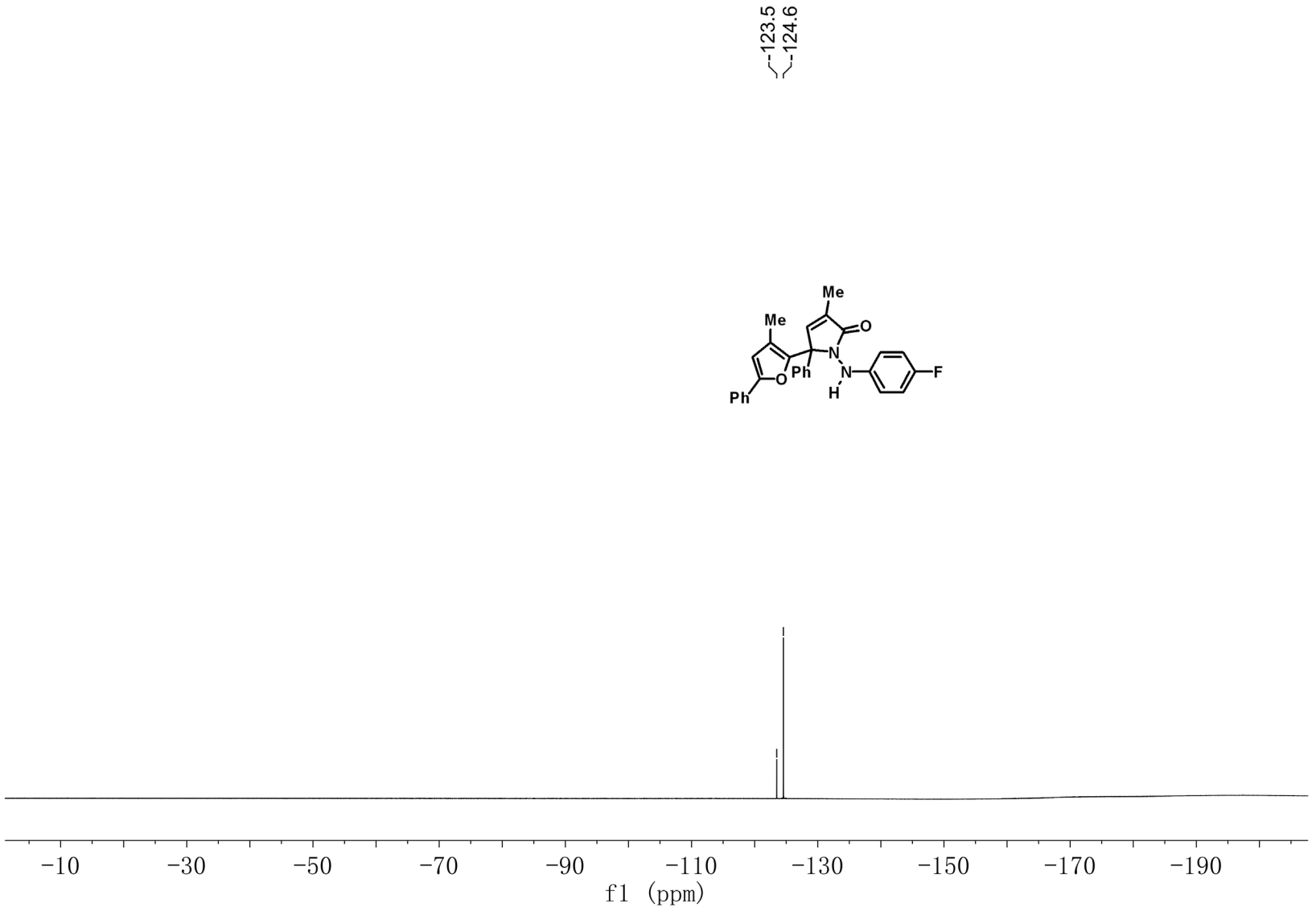
^{13}C NMR Spectrum of Compound **3f**



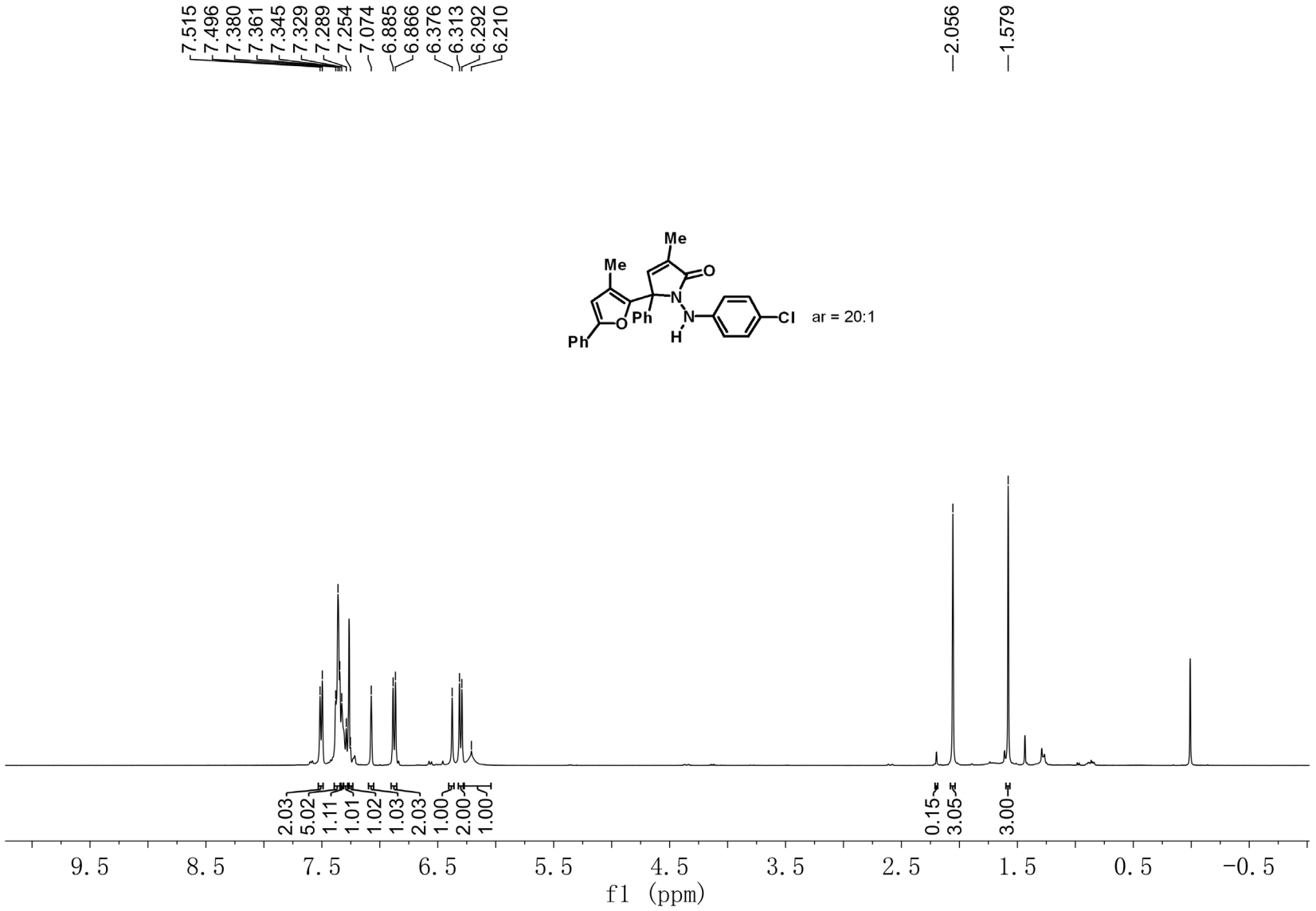
^{1}H NMR Spectrum of Compound **3g**



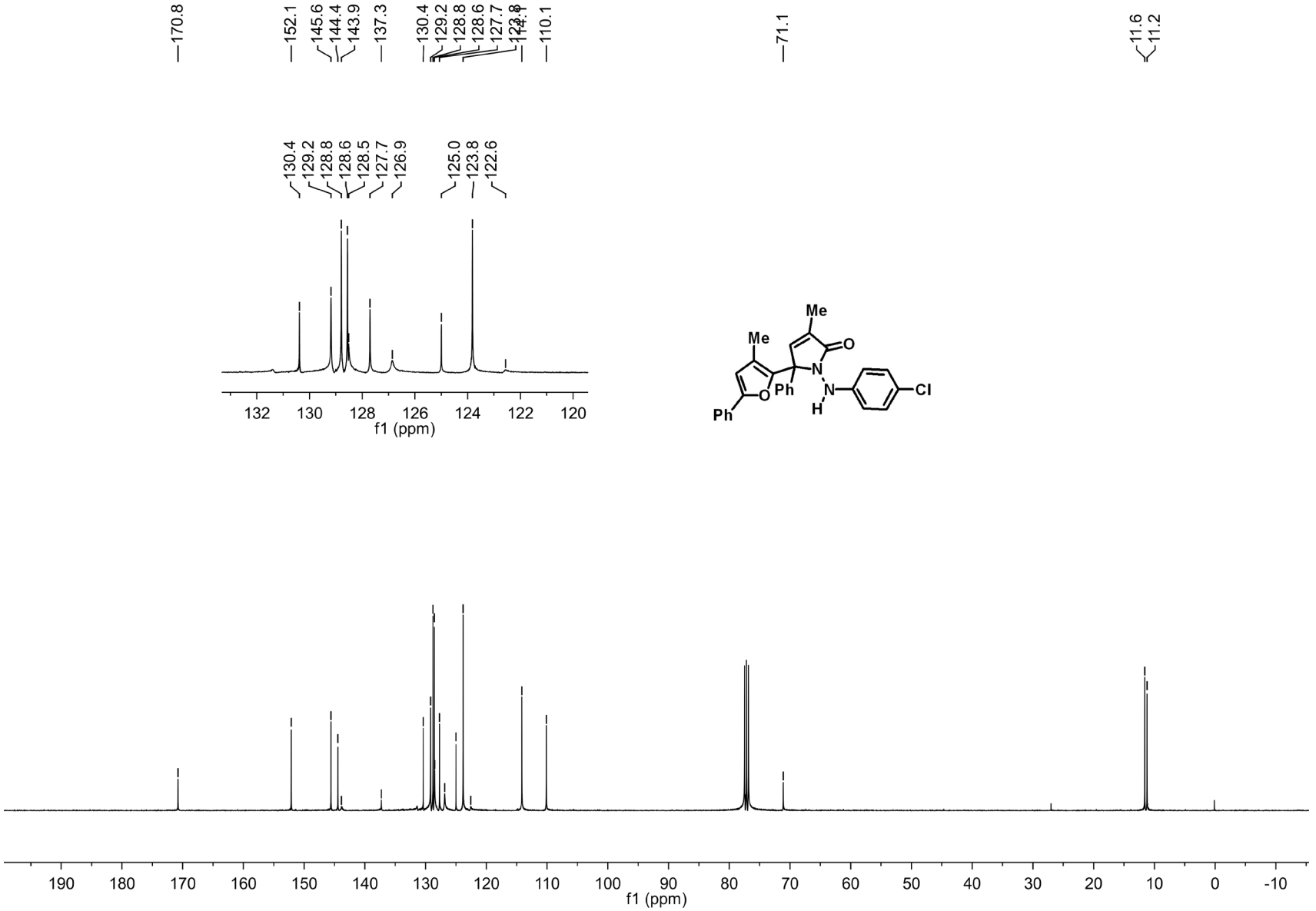
^{13}C NMR Spectrum of Compound **3g**



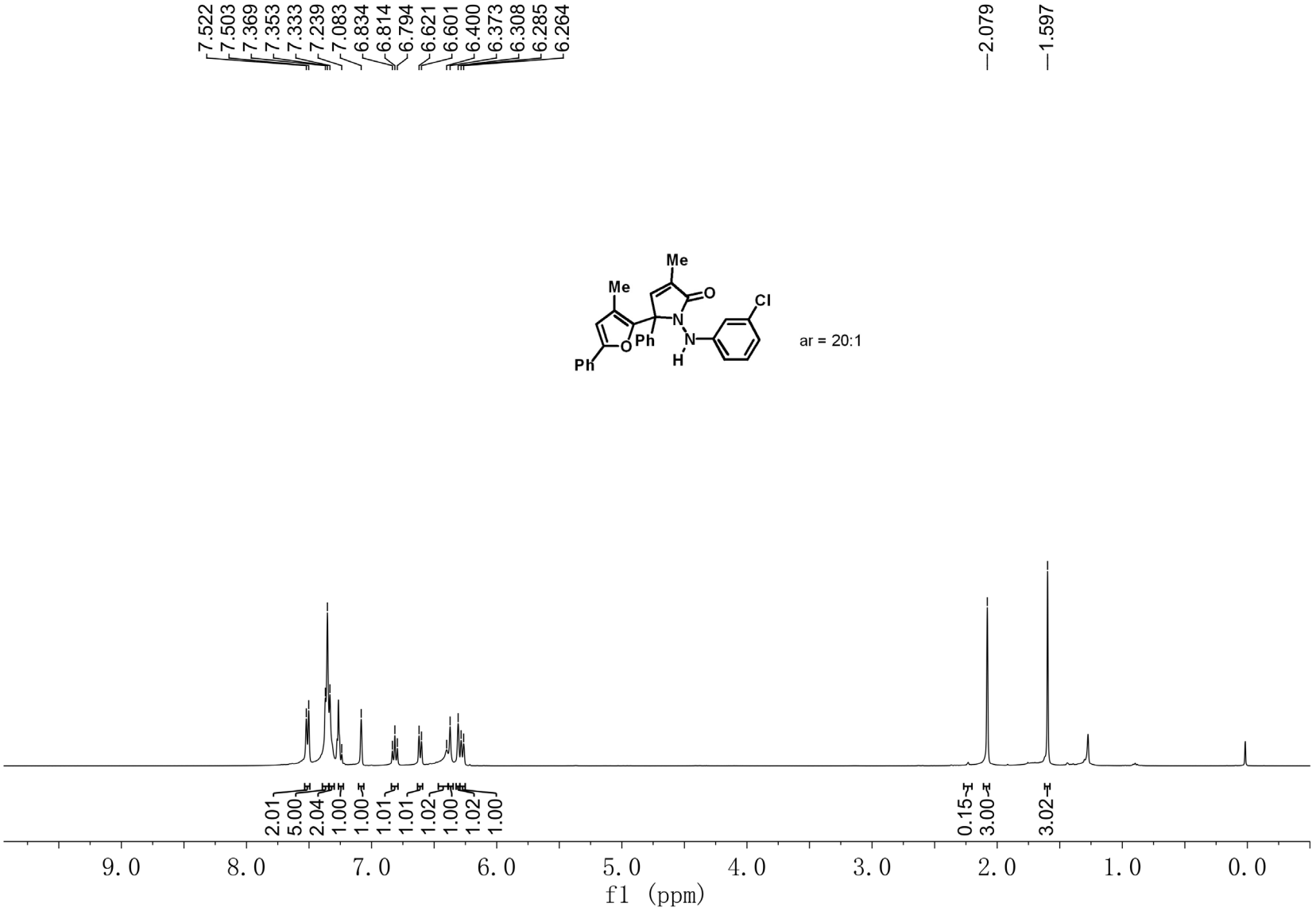
^{19}F NMR Spectrum of Compound **3g**



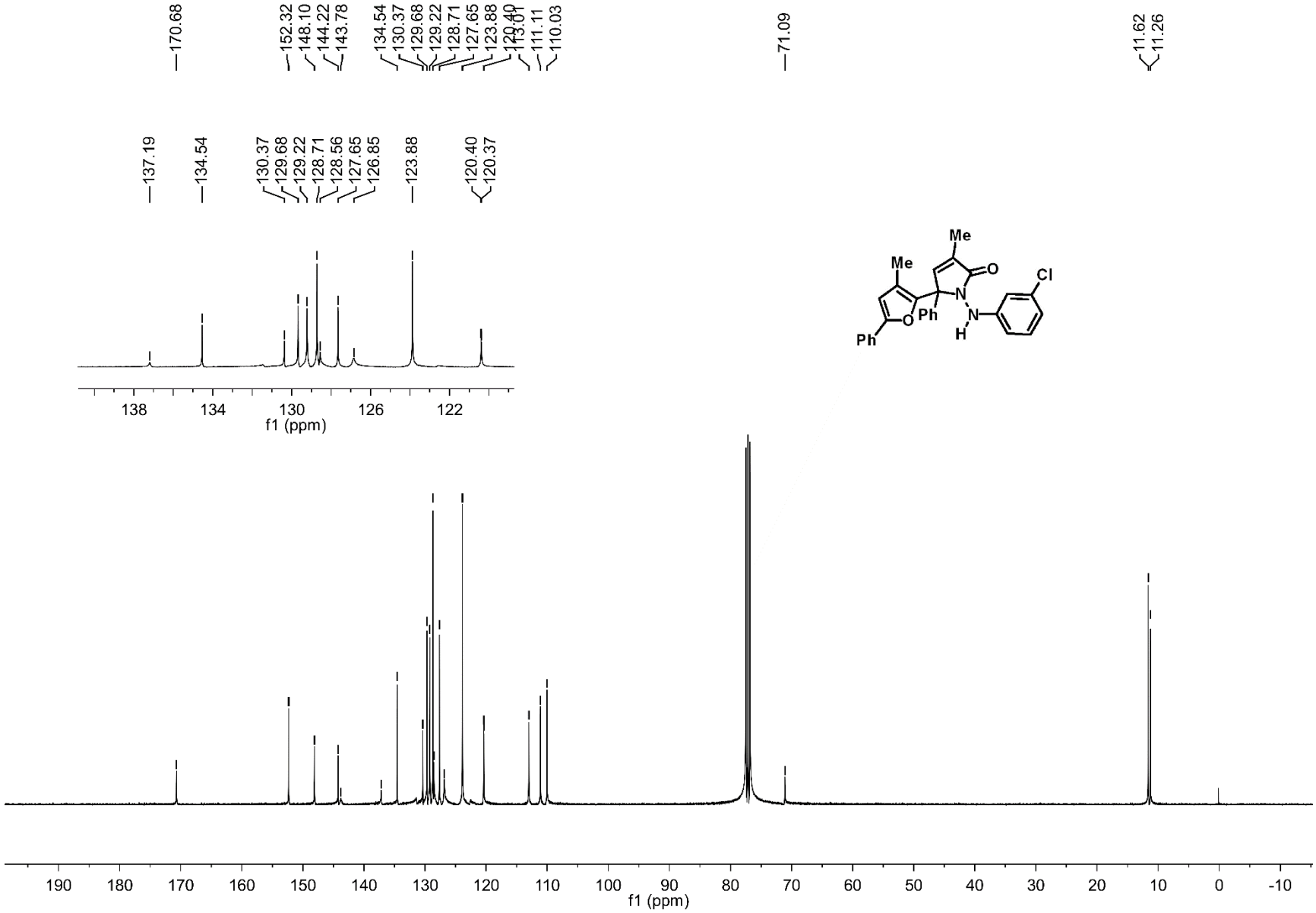
^{1}H NMR Spectrum of Compound **3h**



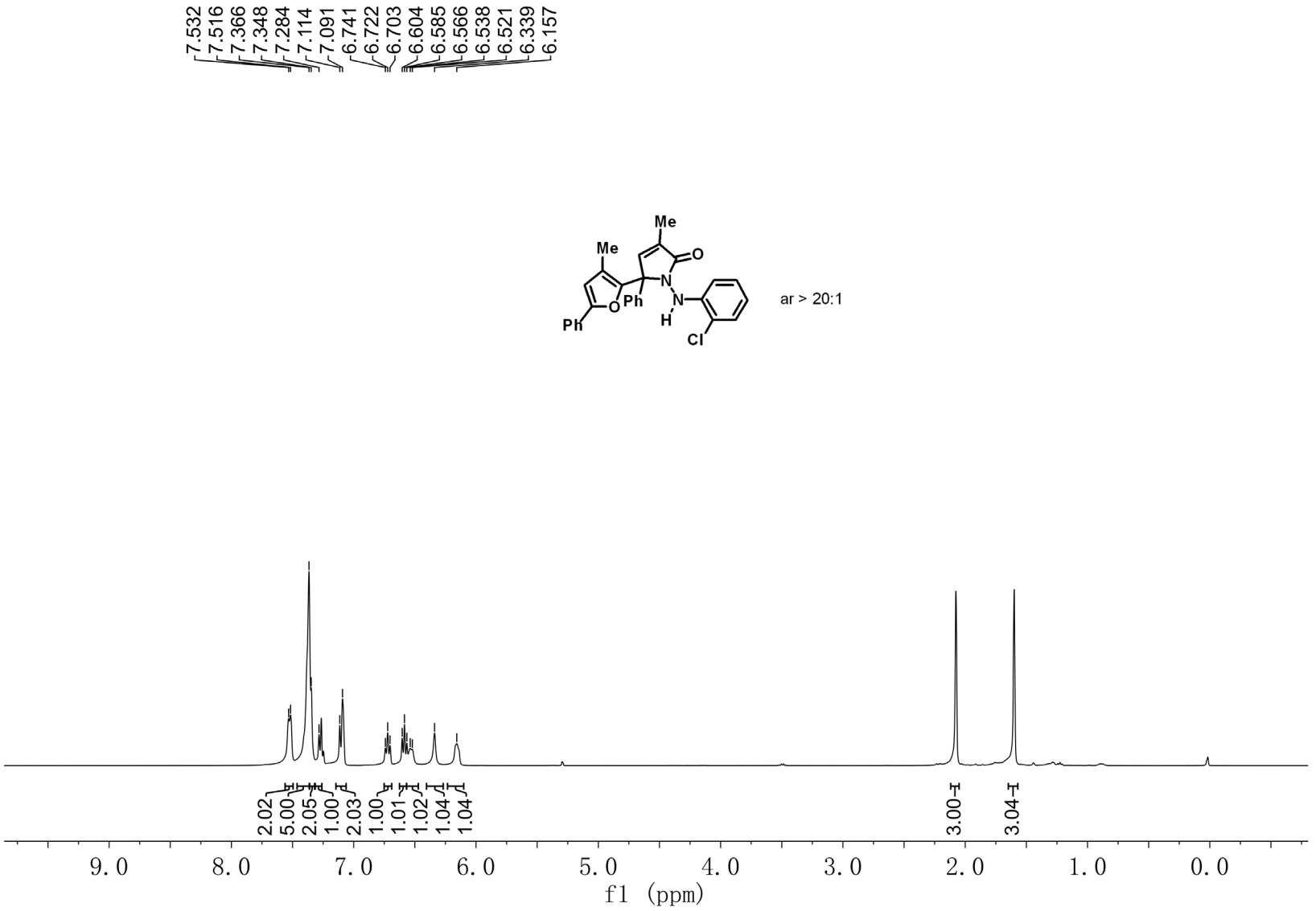
^{13}C NMR Spectrum of Compound **3h**



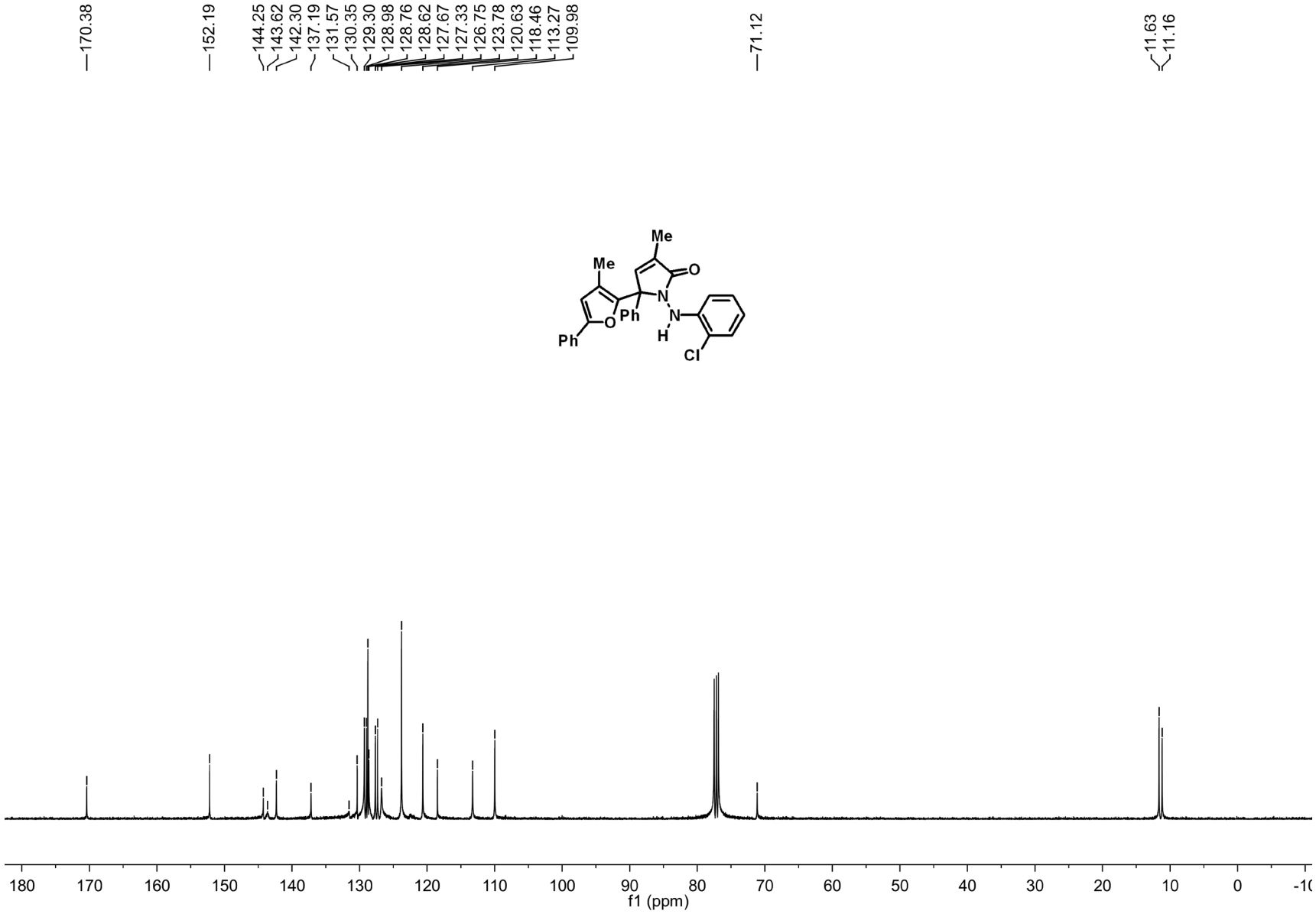
^{1}H NMR Spectrum of Compound **3i**



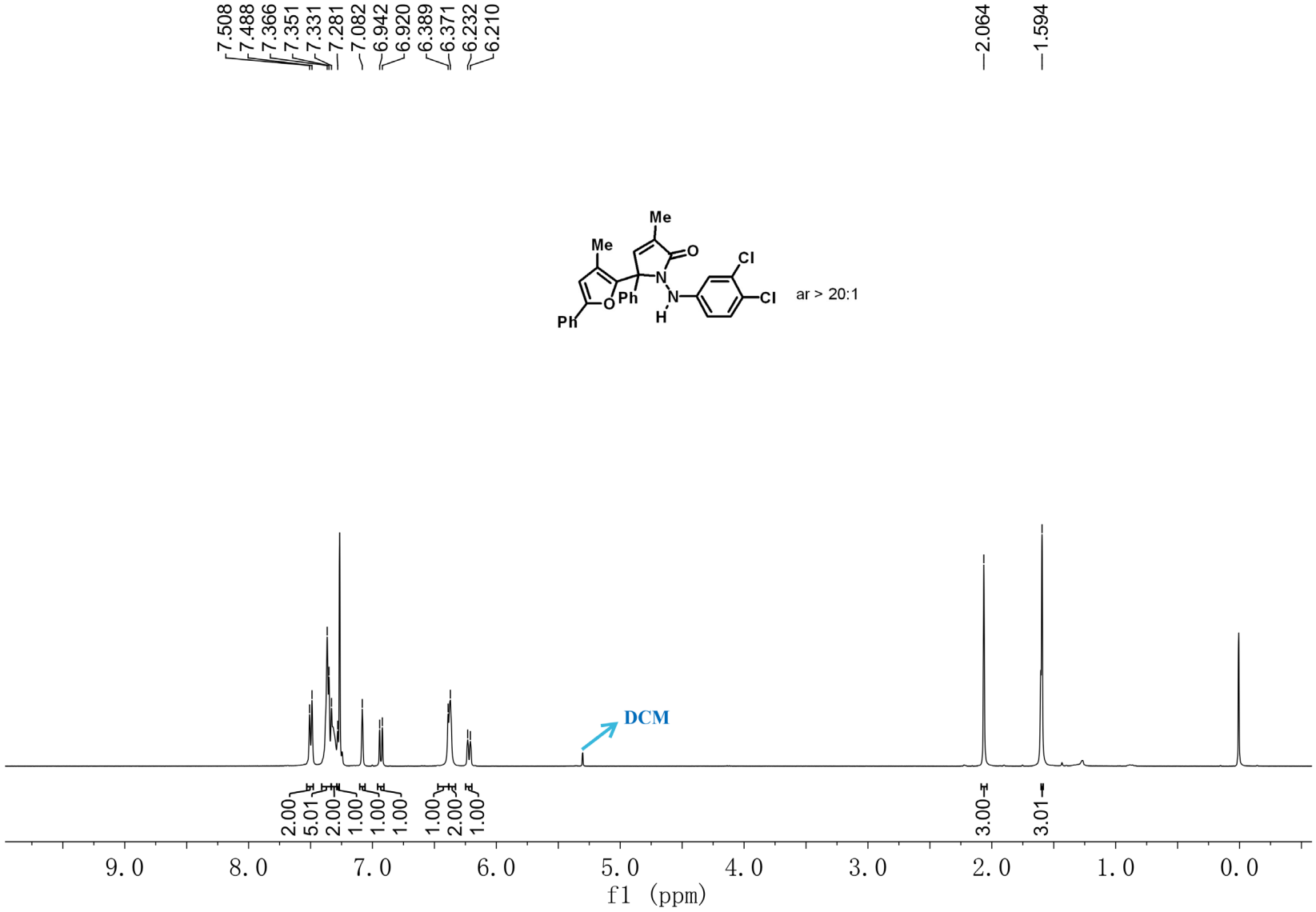
^{13}C NMR Spectrum of Compound **3i**



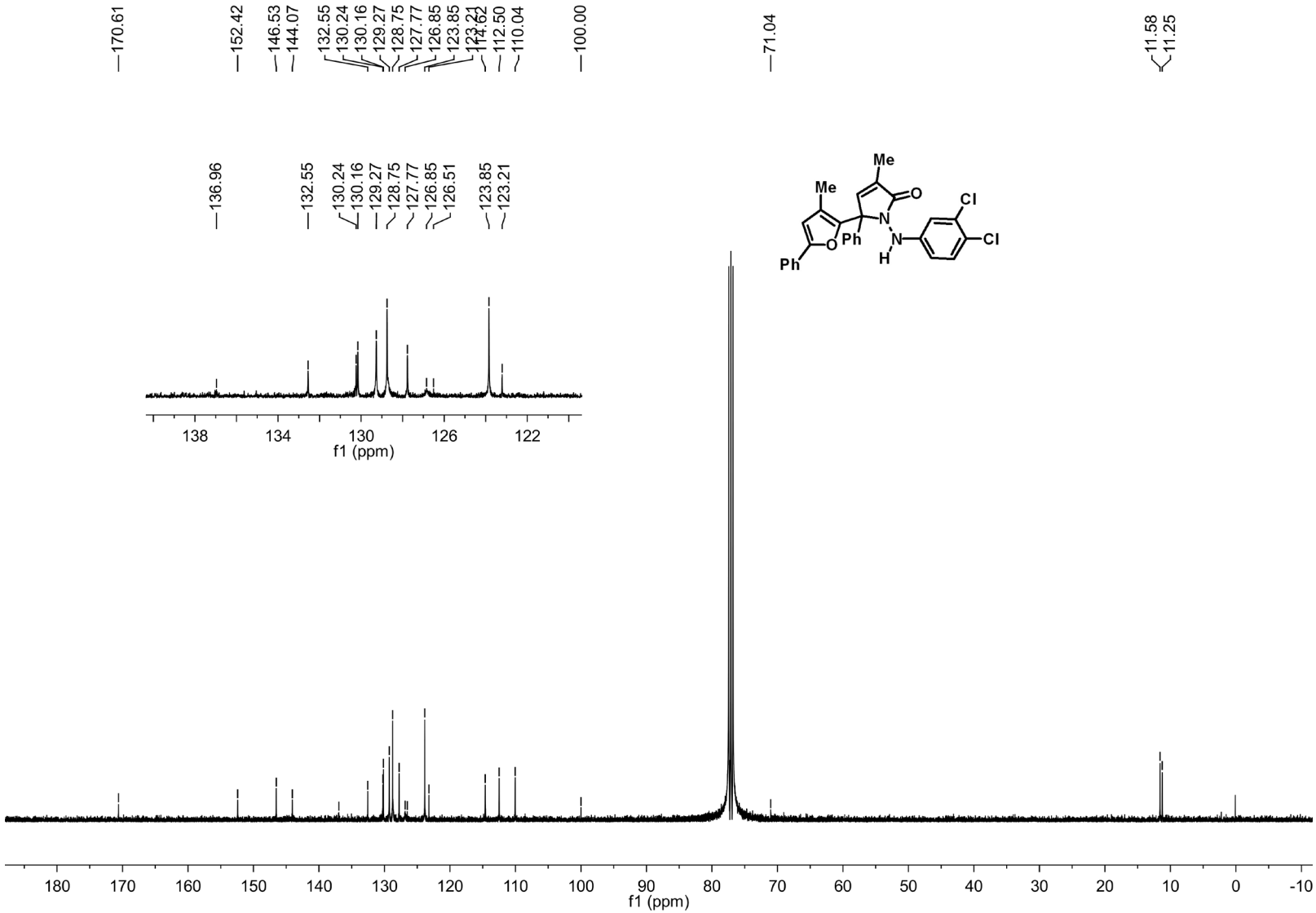
^{1}H NMR Spectrum of Compound **3j**



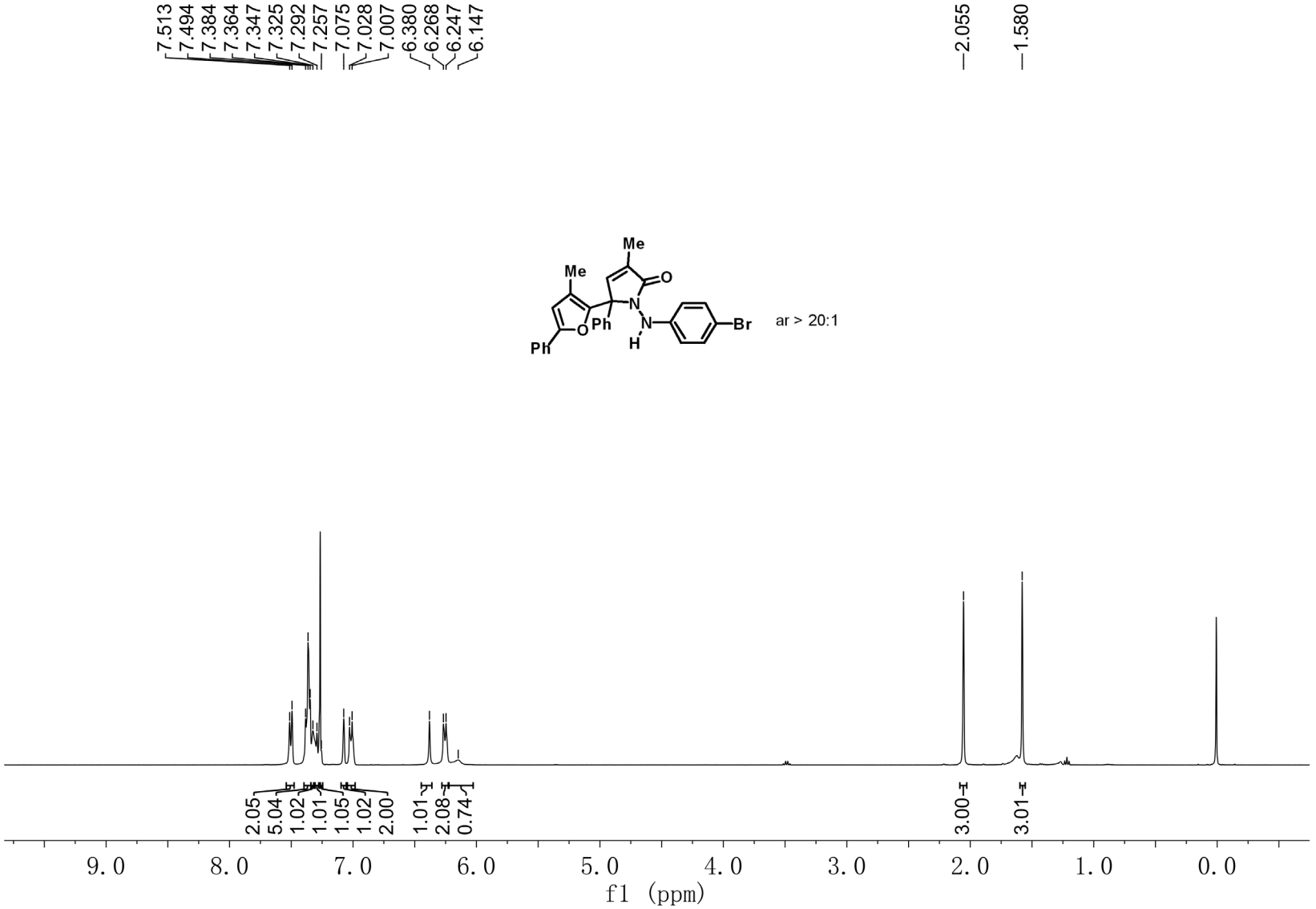
^{13}C NMR Spectrum of Compound **3j**



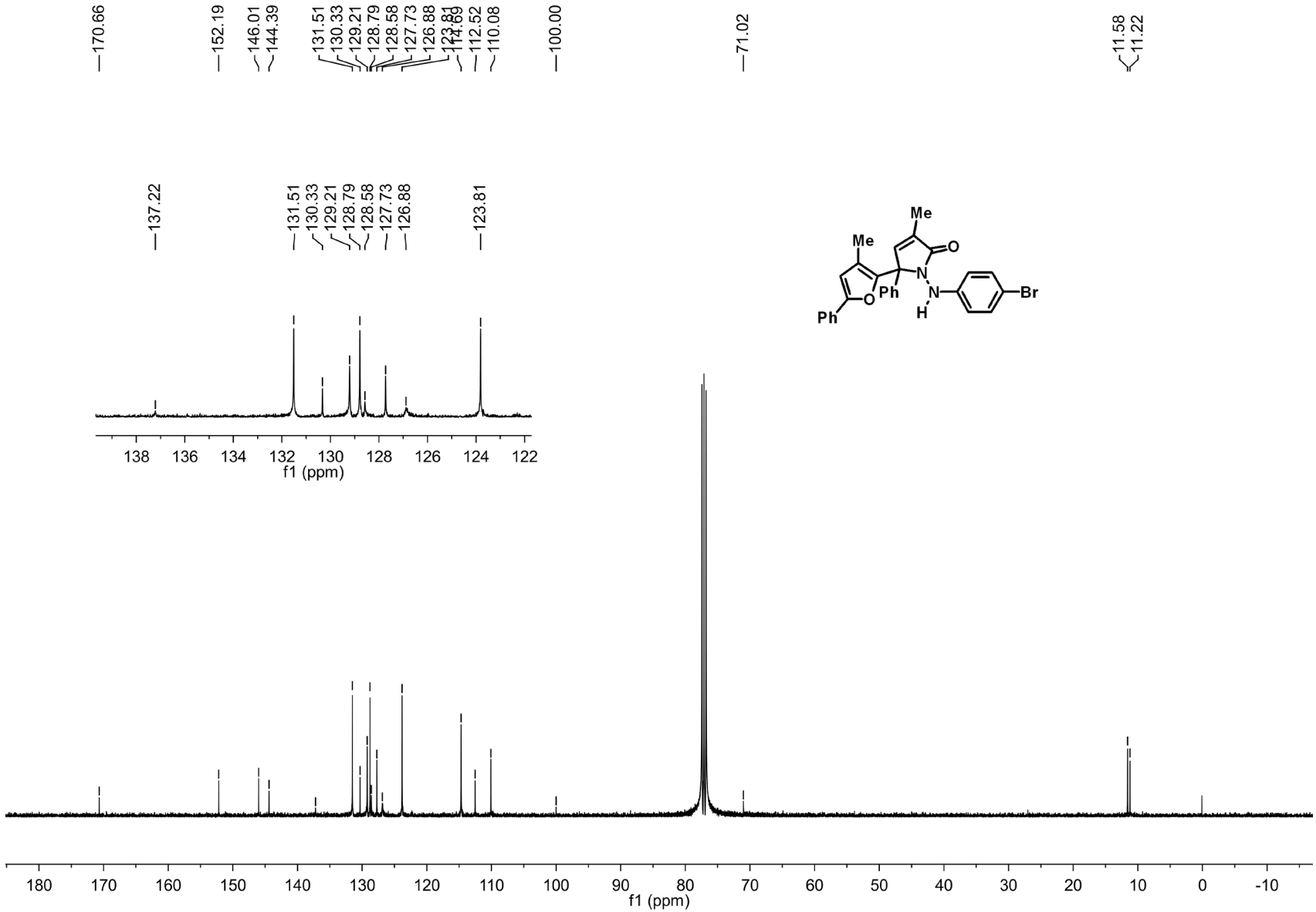
^{1}H NMR Spectrum of Compound **3k**



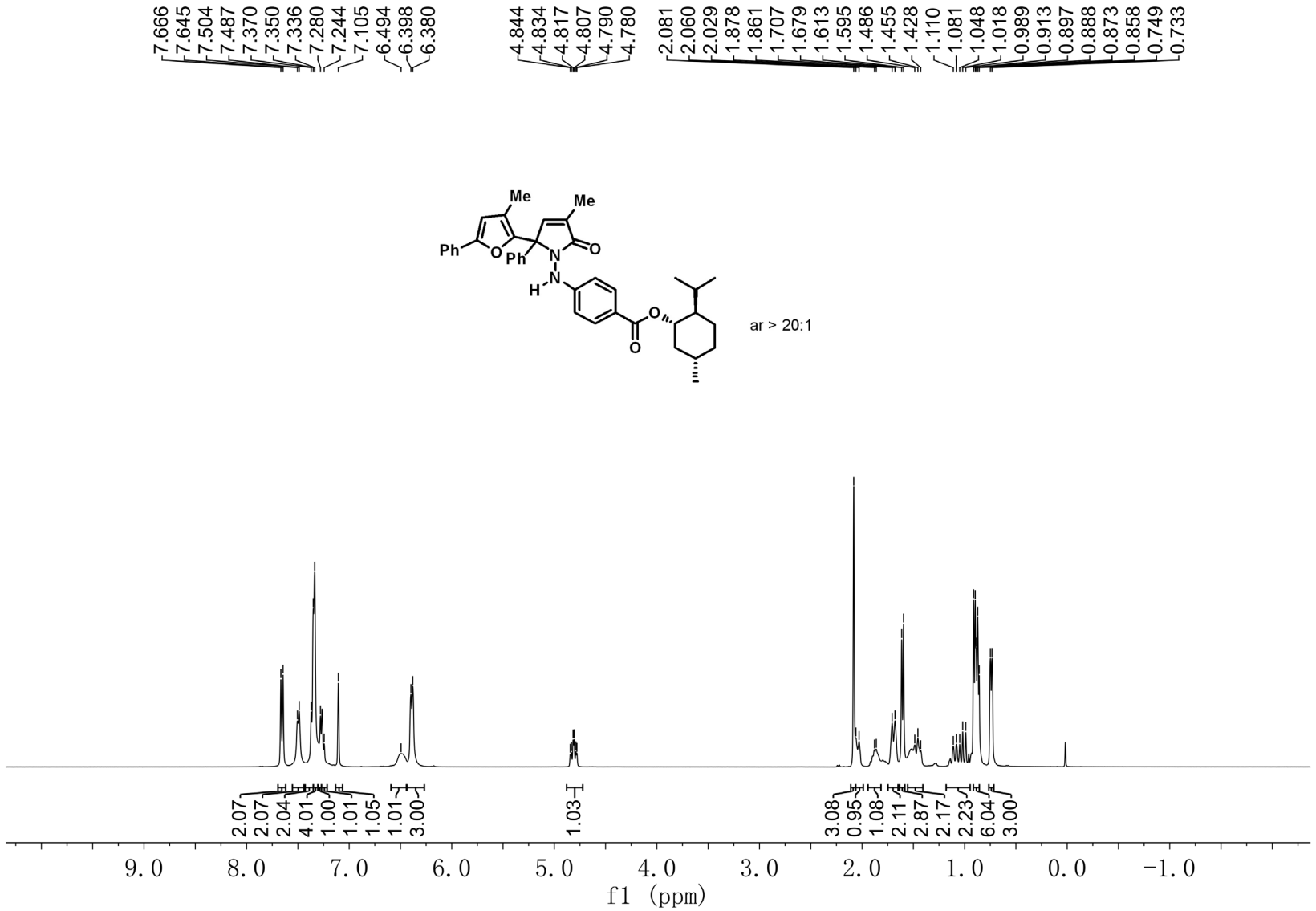
^{13}C NMR Spectrum of Compound **3k**



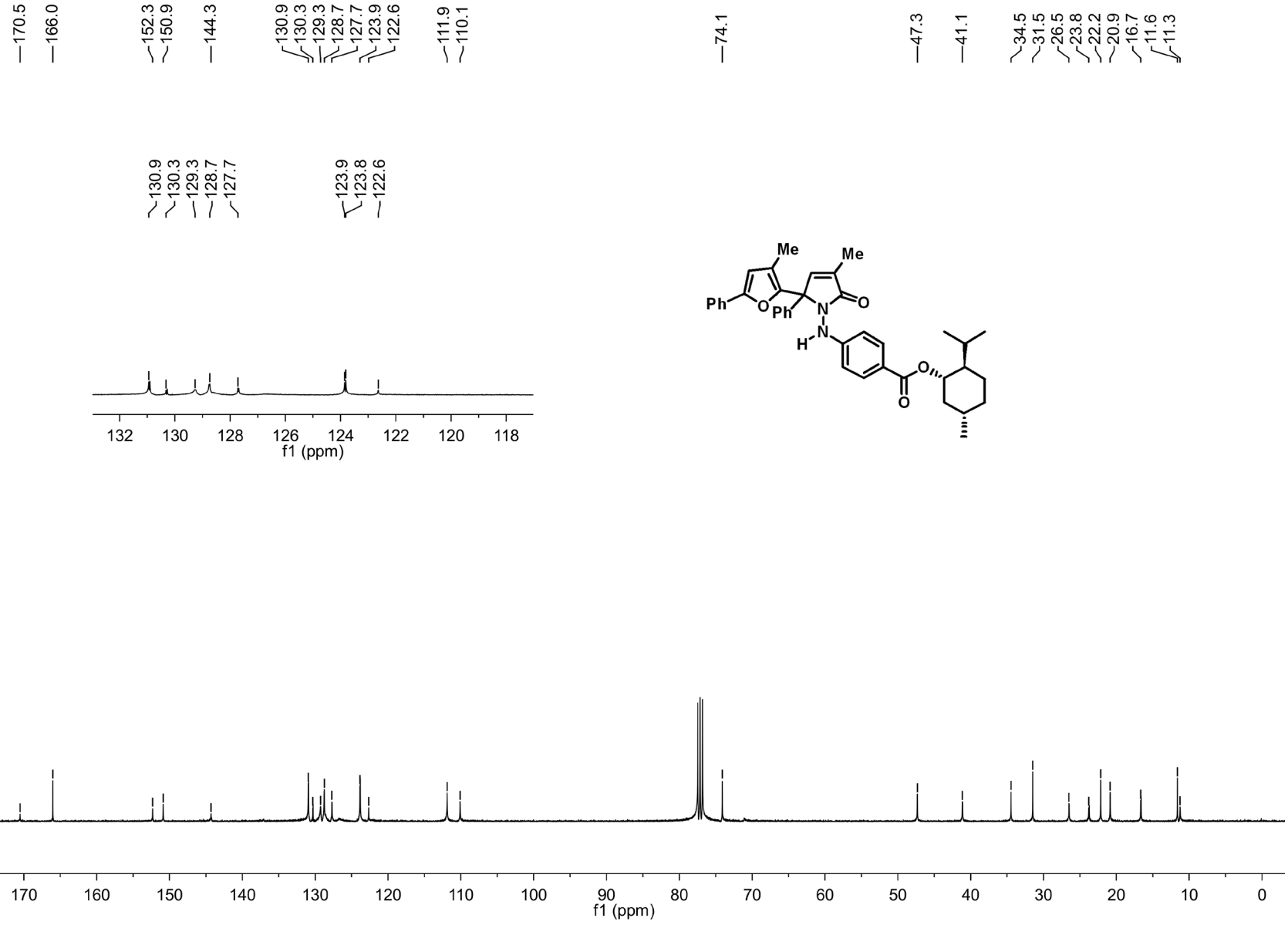
^{1}H NMR Spectrum of Compound **3l**



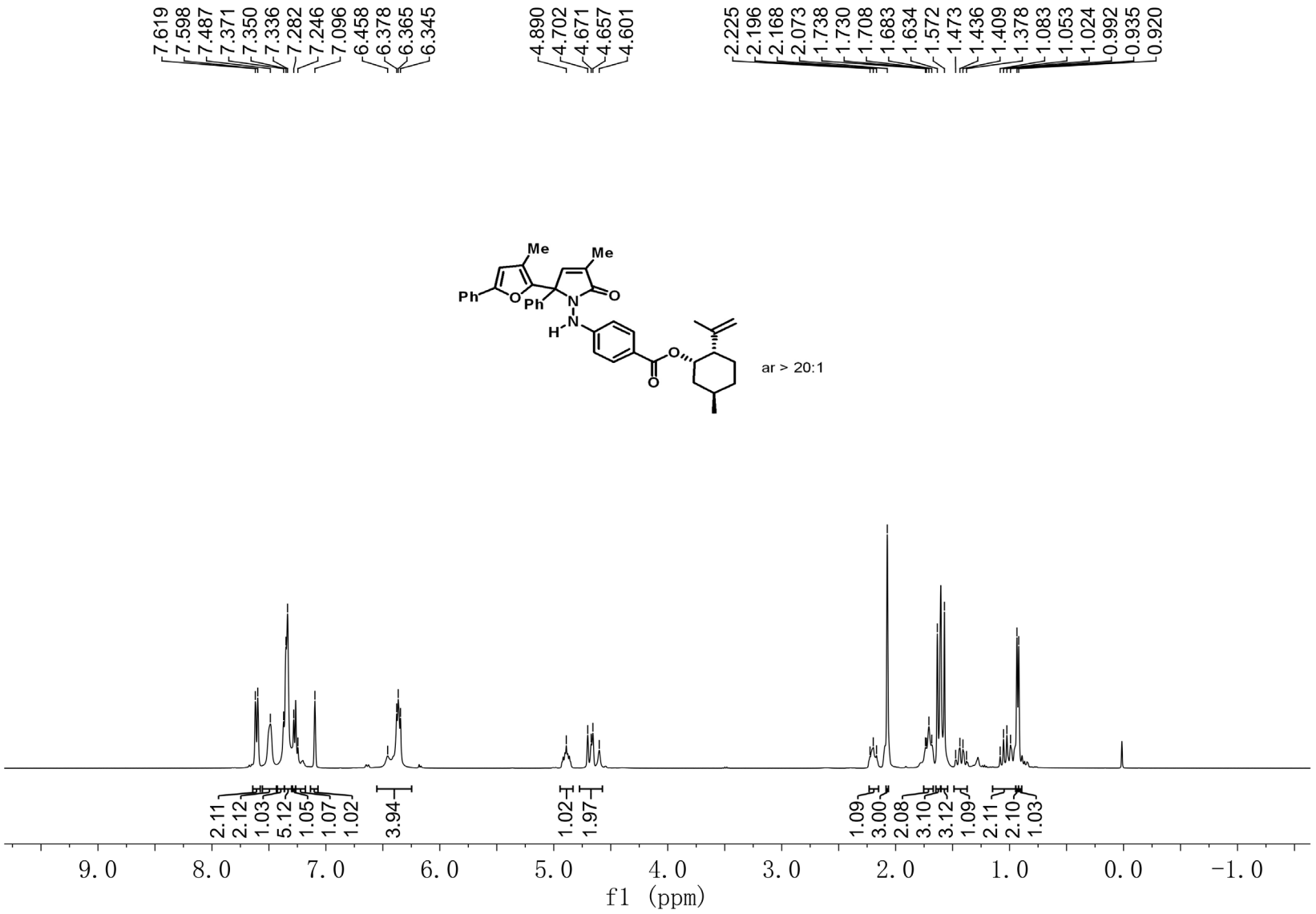
^{13}C NMR Spectrum of Compound **3l**



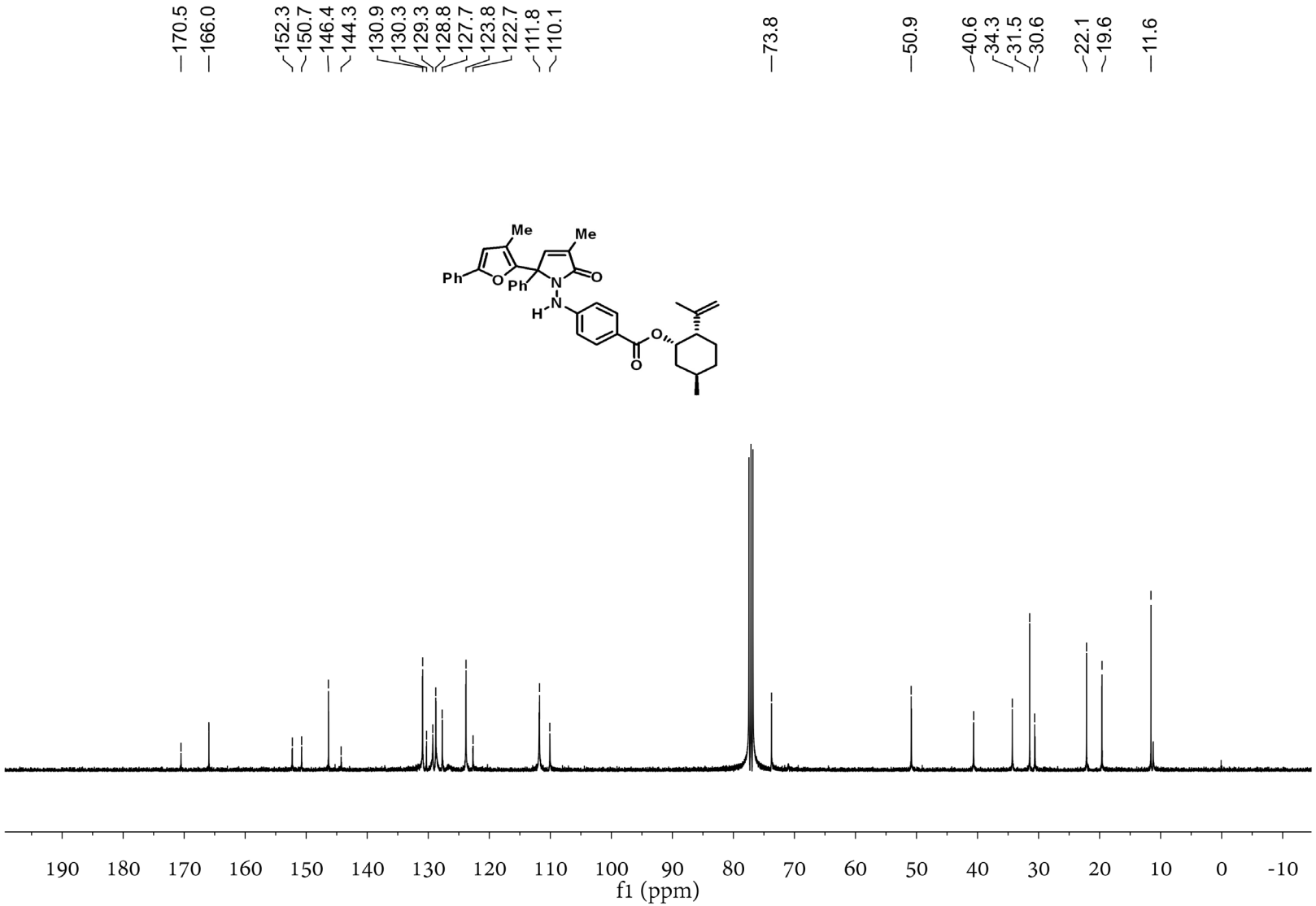
^{1}H NMR Spectrum of Compound **3n**



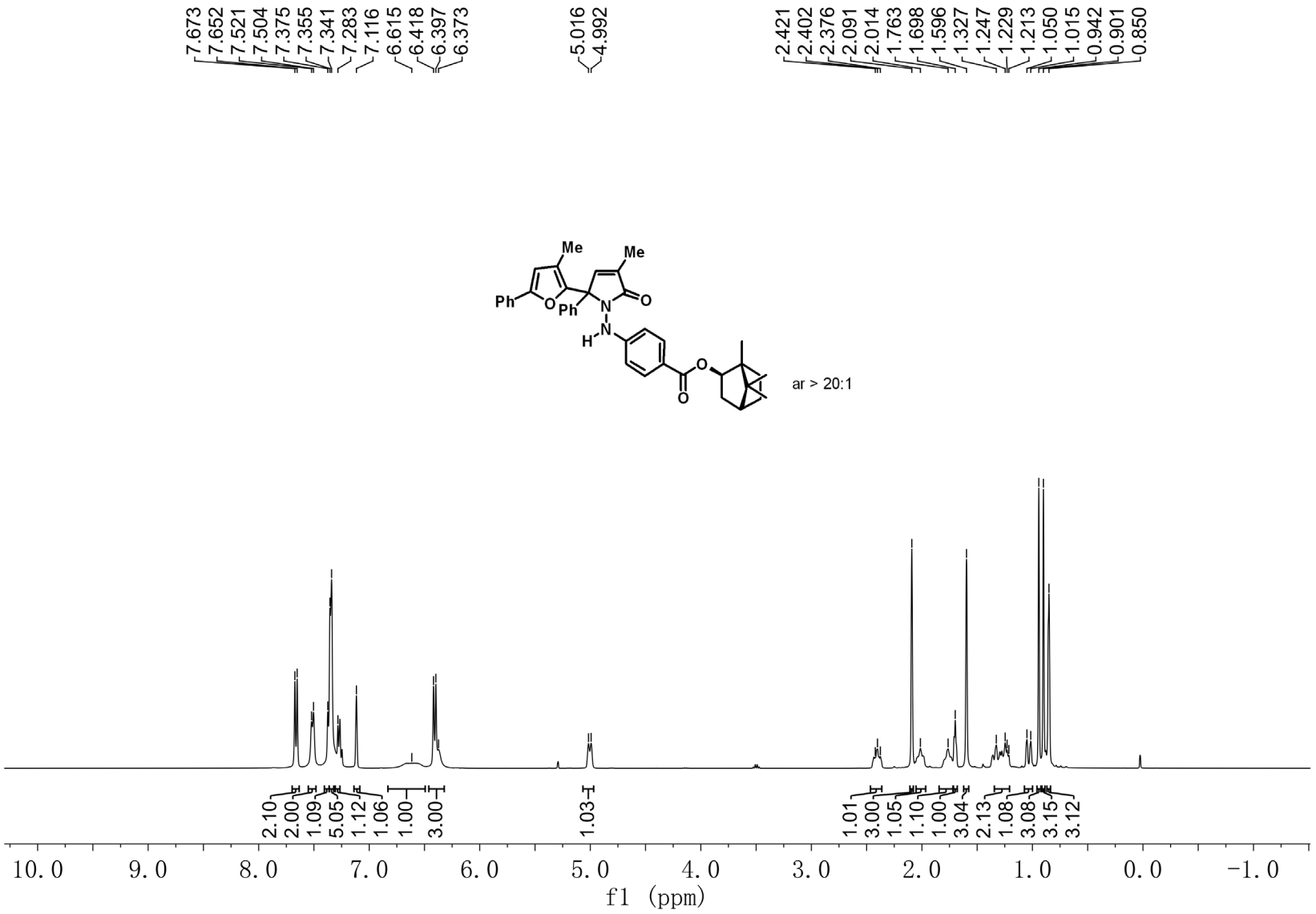
^{13}C NMR Spectrum of Compound **3n**



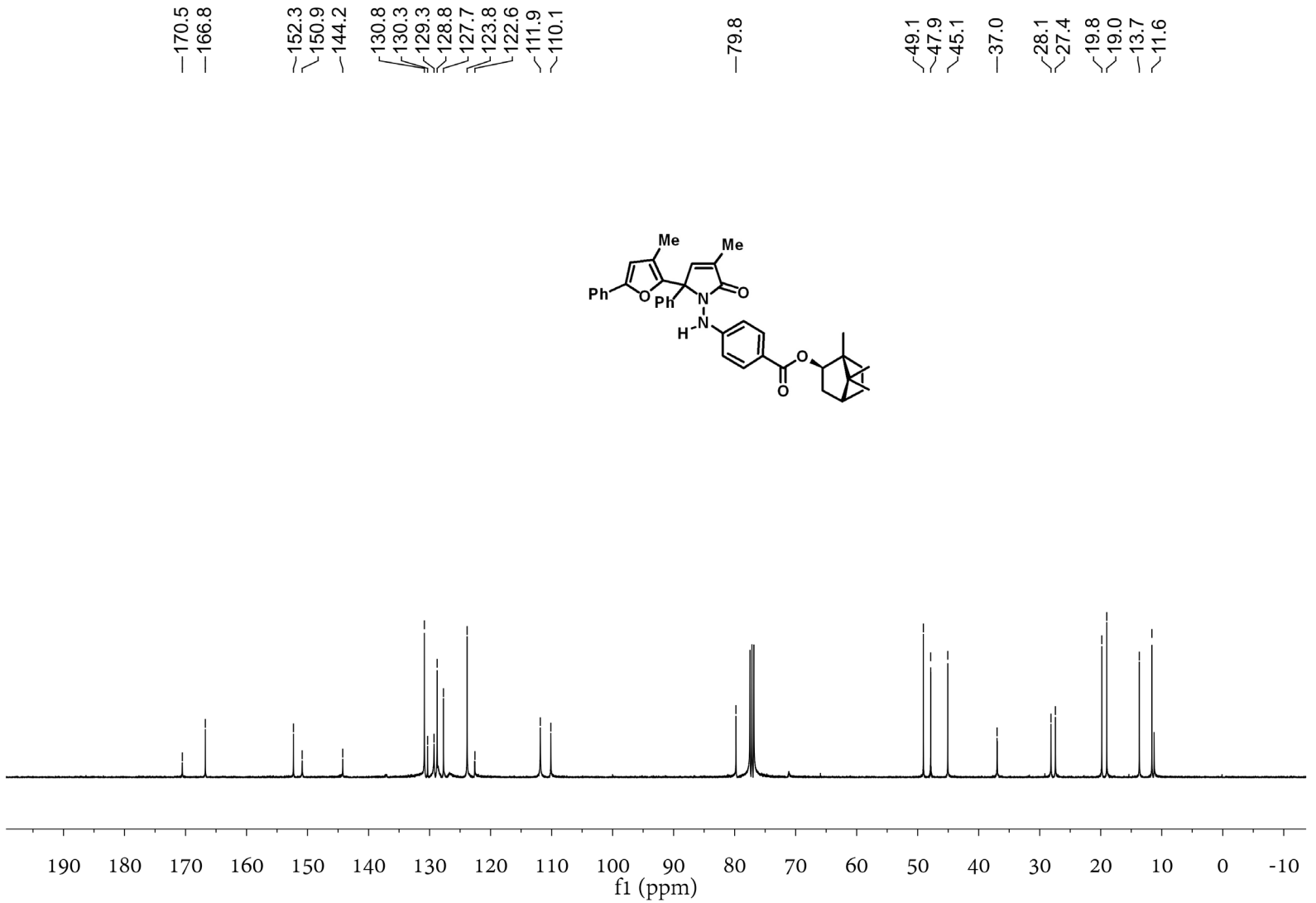
^{1}H NMR Spectrum of Compound **3o**



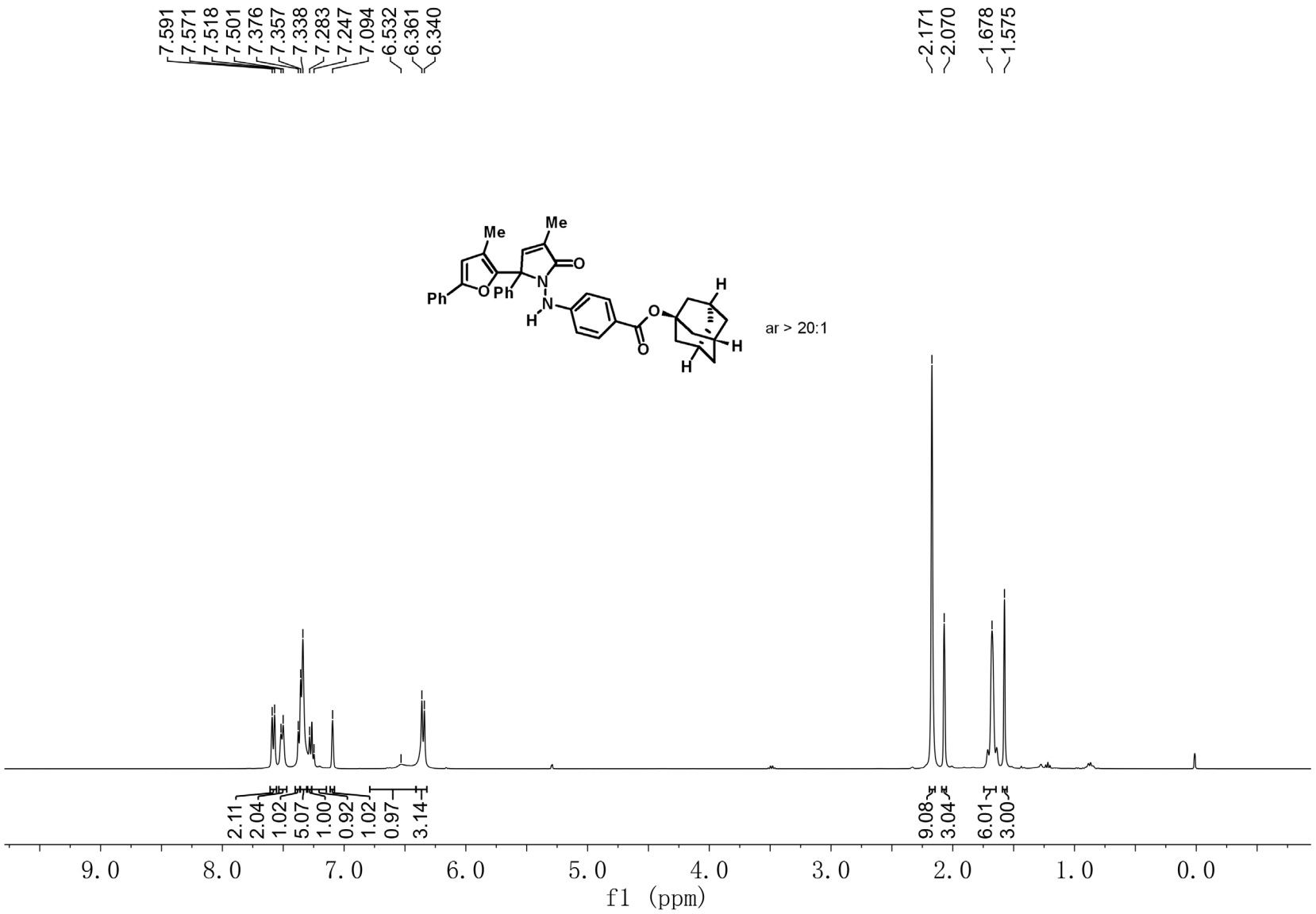
^{13}C NMR Spectrum of Compound **3o**



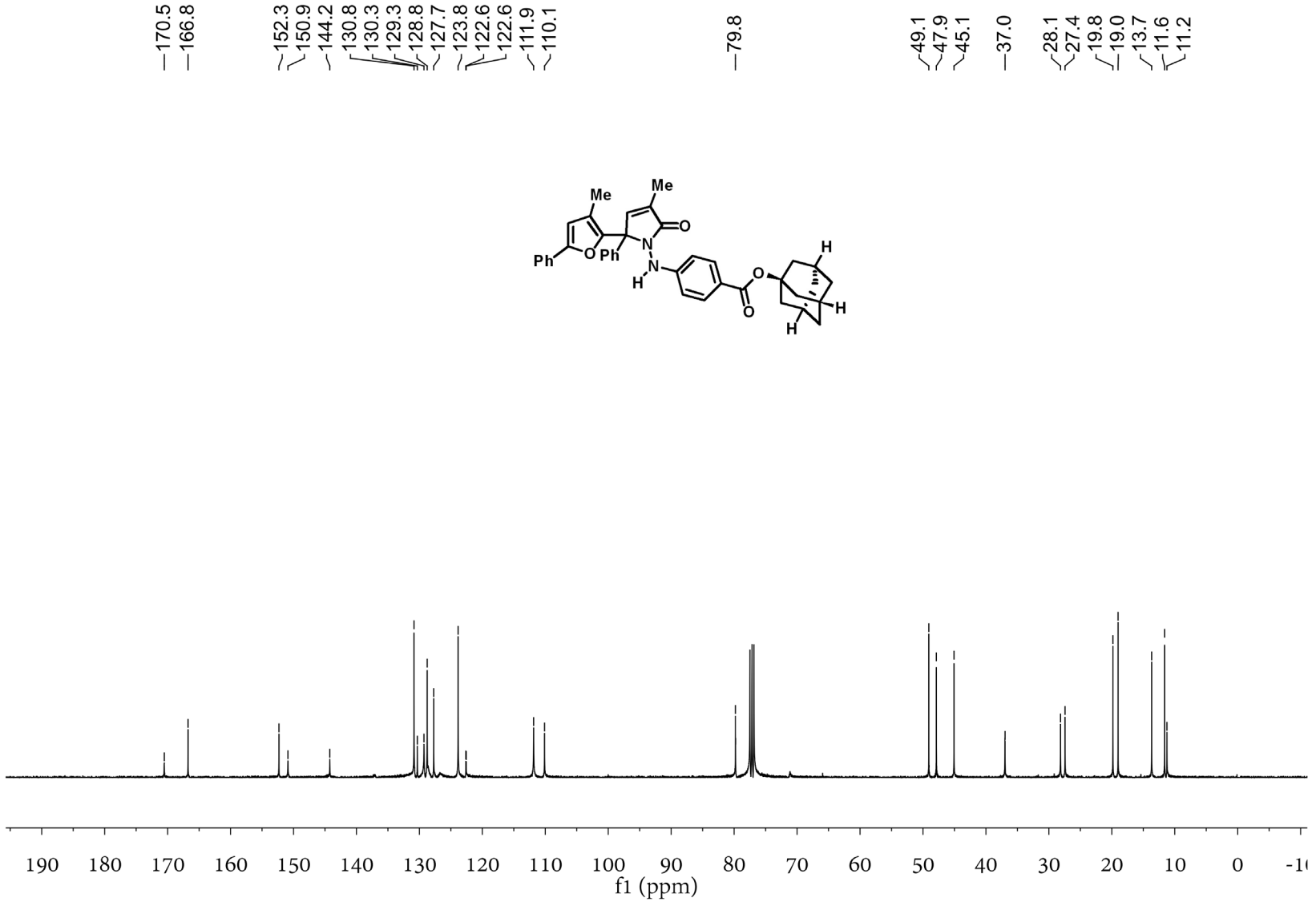
^{1}H NMR Spectrum of Compound **3p**



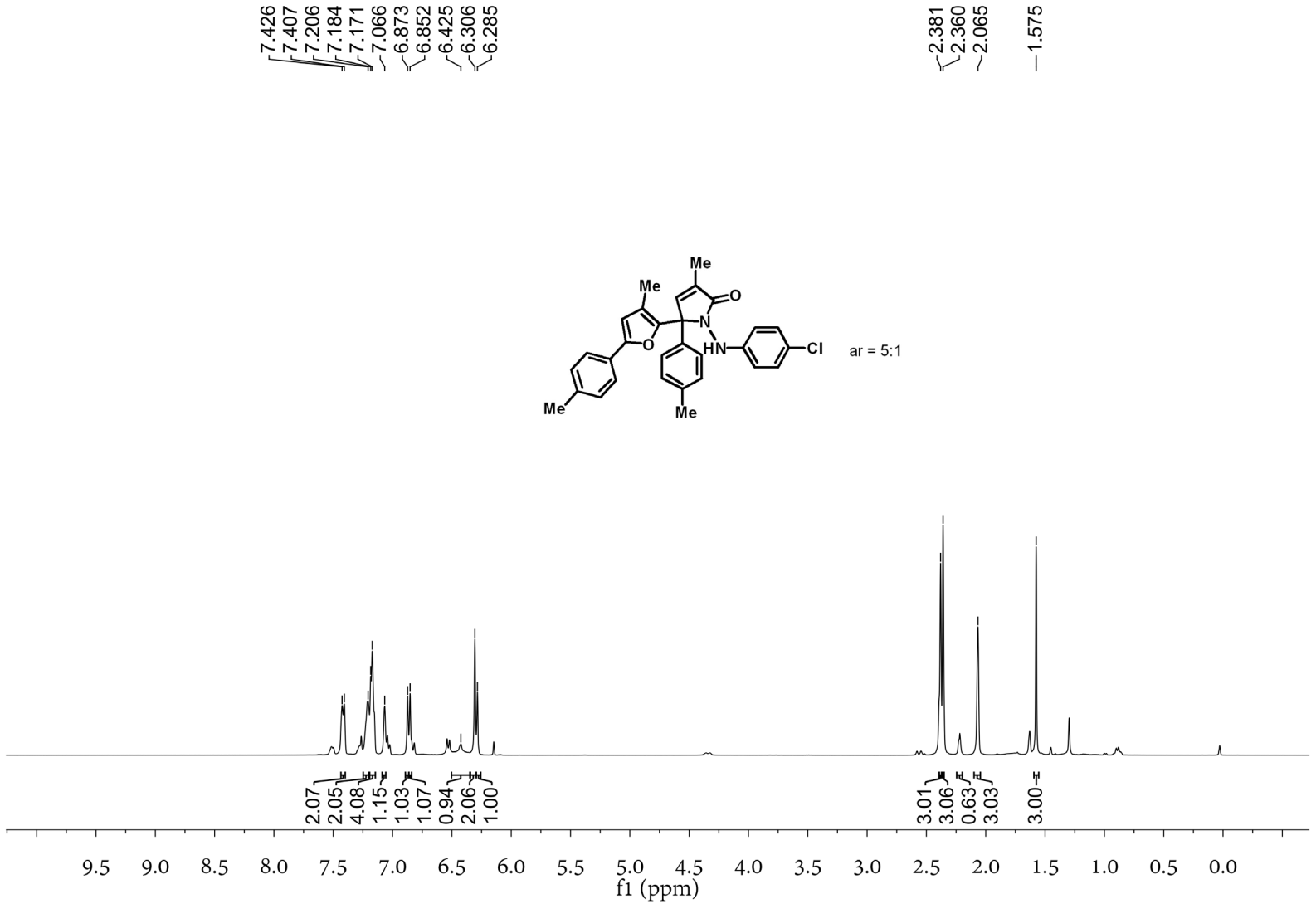
^{13}C NMR Spectrum of Compound **3p**



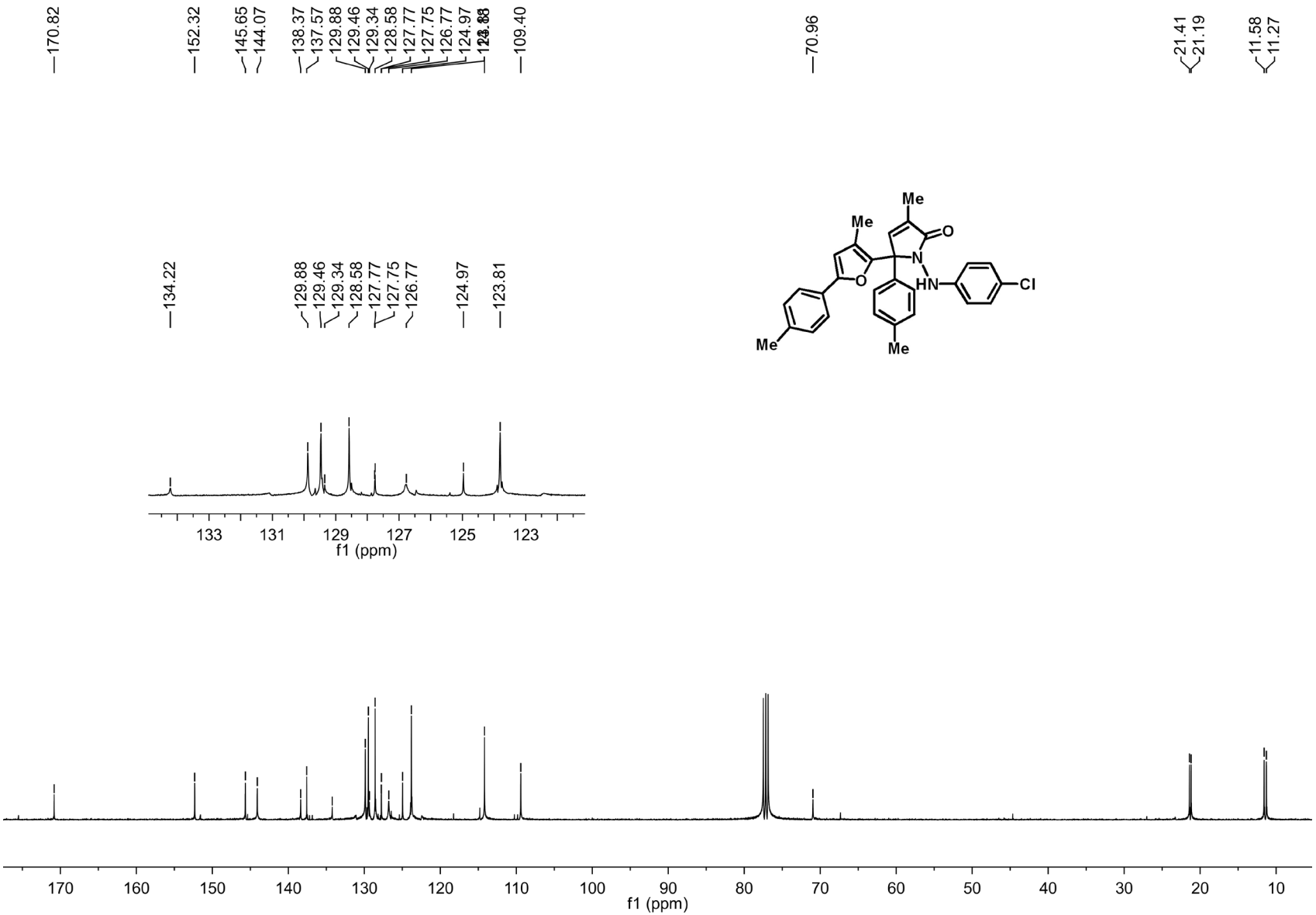
^{1}H NMR Spectrum of Compound **3q**



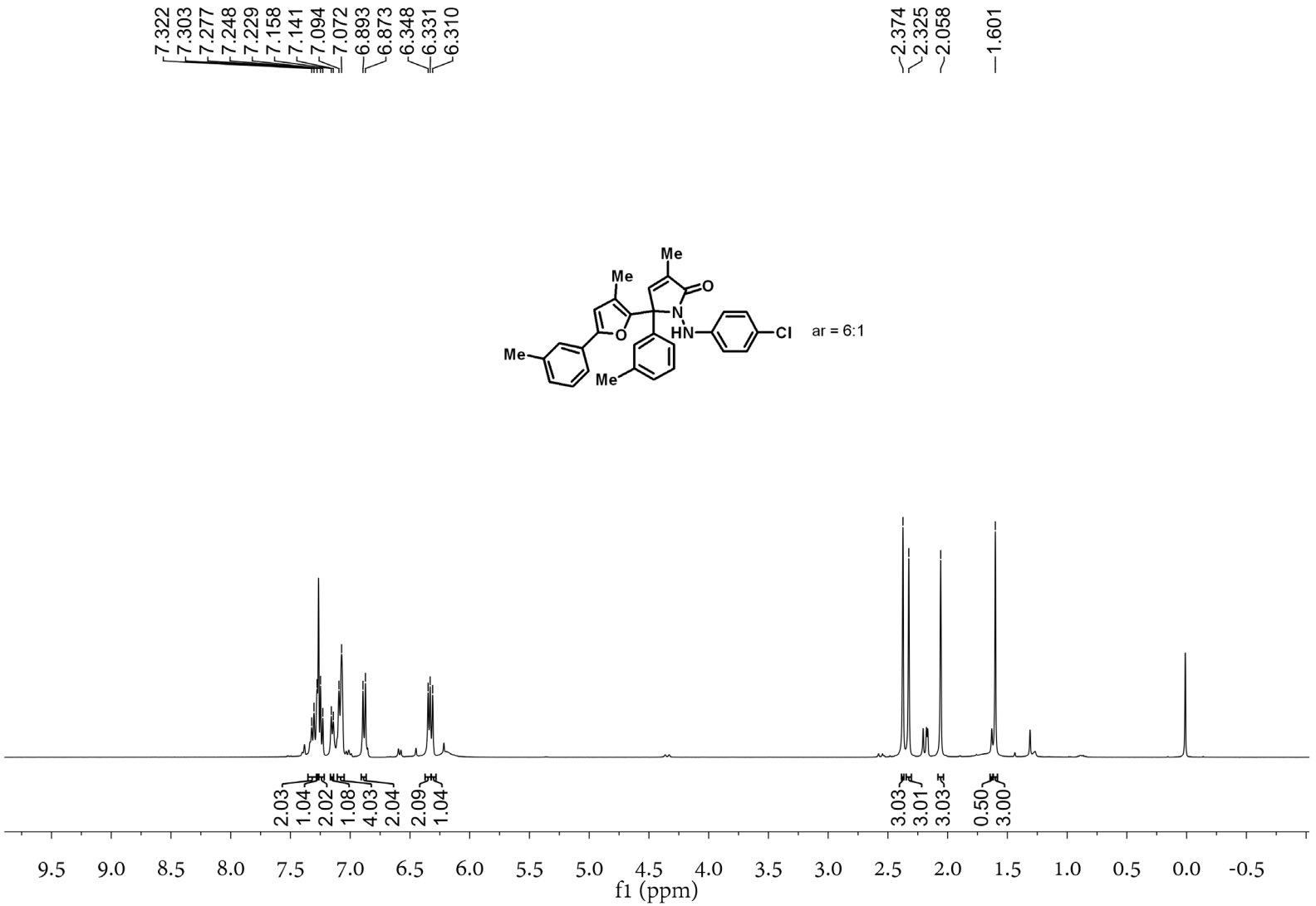
^{13}C NMR Spectrum of Compound **3q**



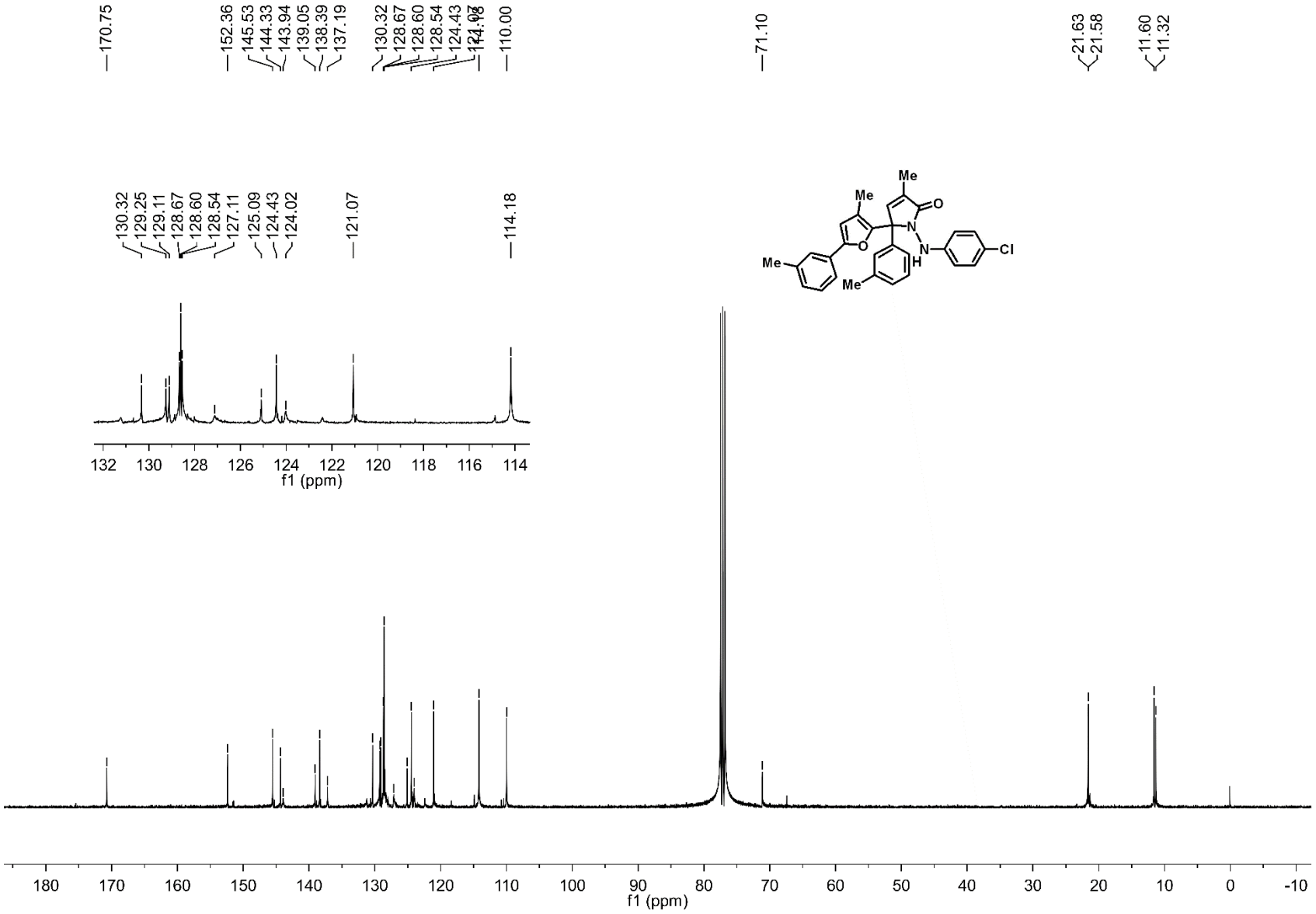
^{1}H NMR Spectrum of Compound **3r**



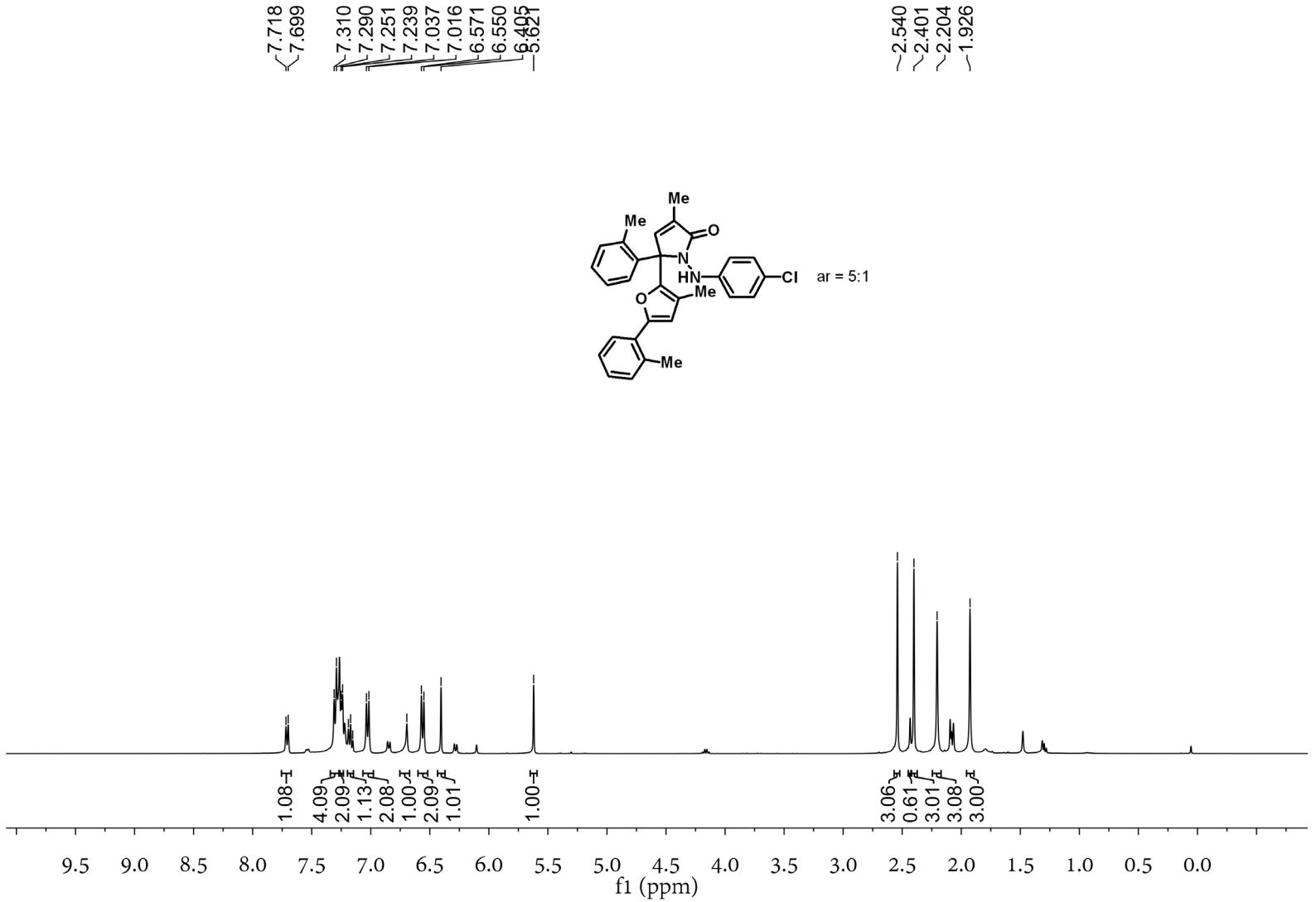
^{13}C NMR Spectrum of Compound **3r**



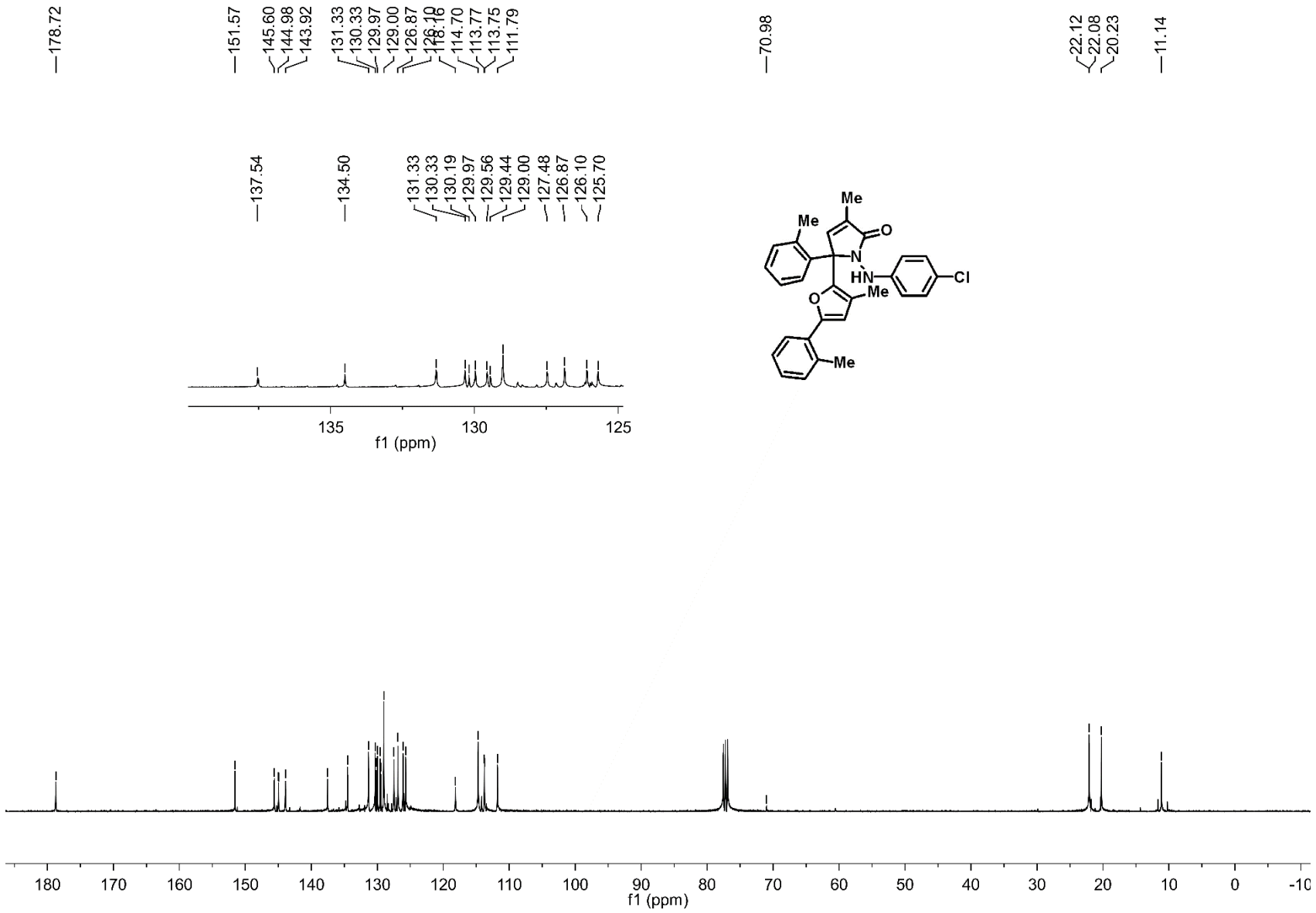
^{1}H NMR Spectrum of Compound **3s**



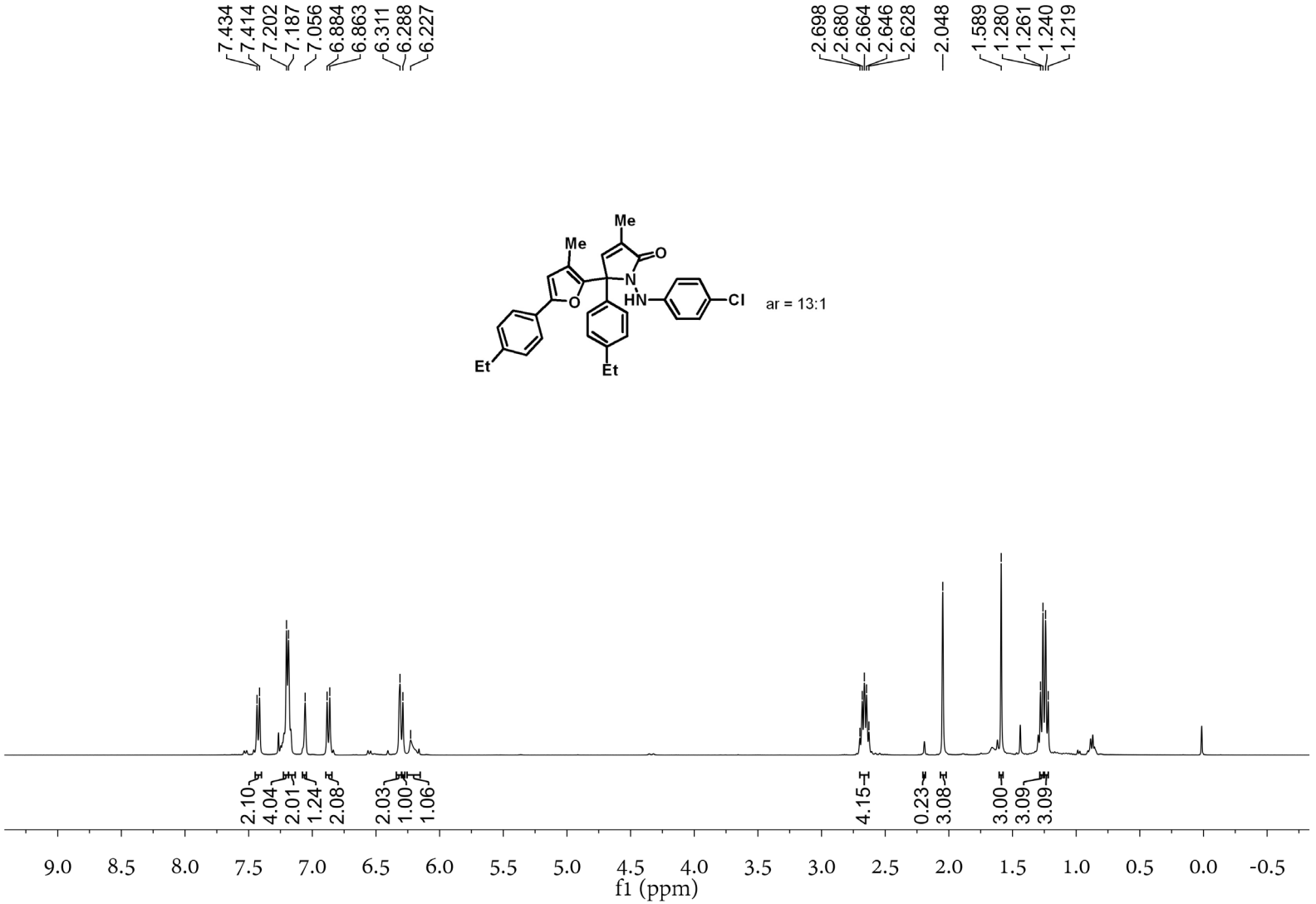
^{13}C NMR Spectrum of Compound **3s**



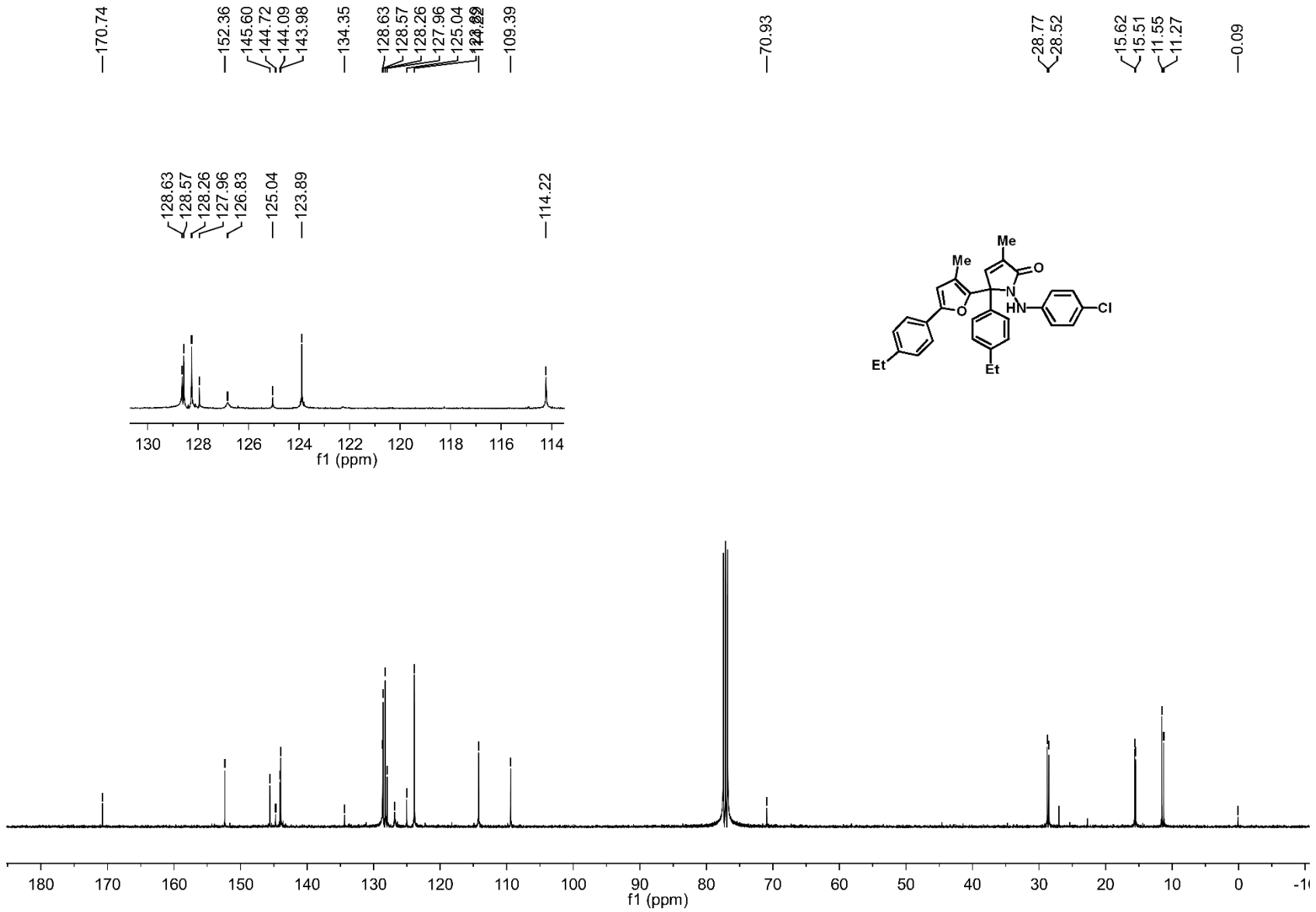
^{1}H NMR Spectrum of Compound **3t**



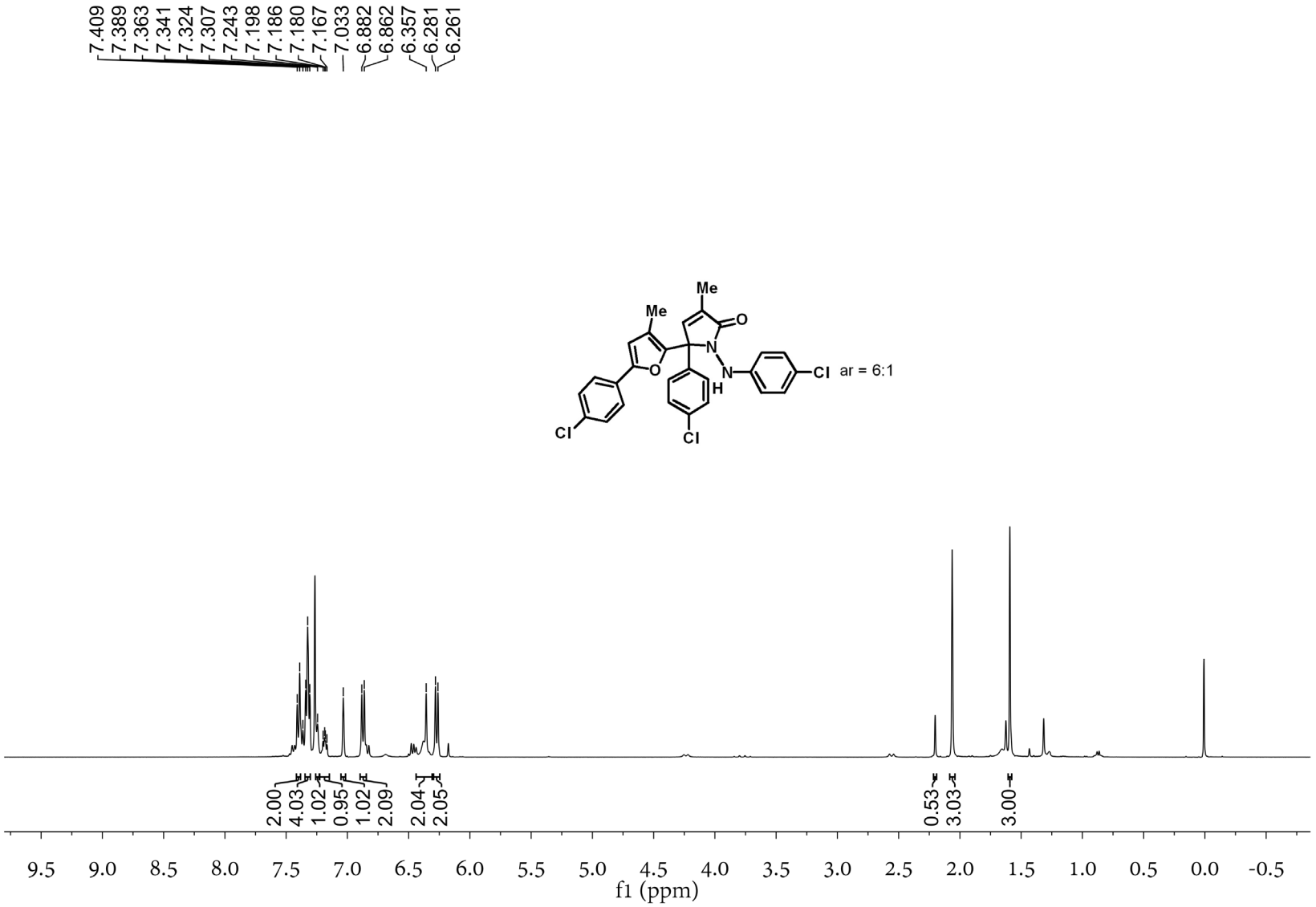
^{13}C NMR Spectrum of Compound **3t**



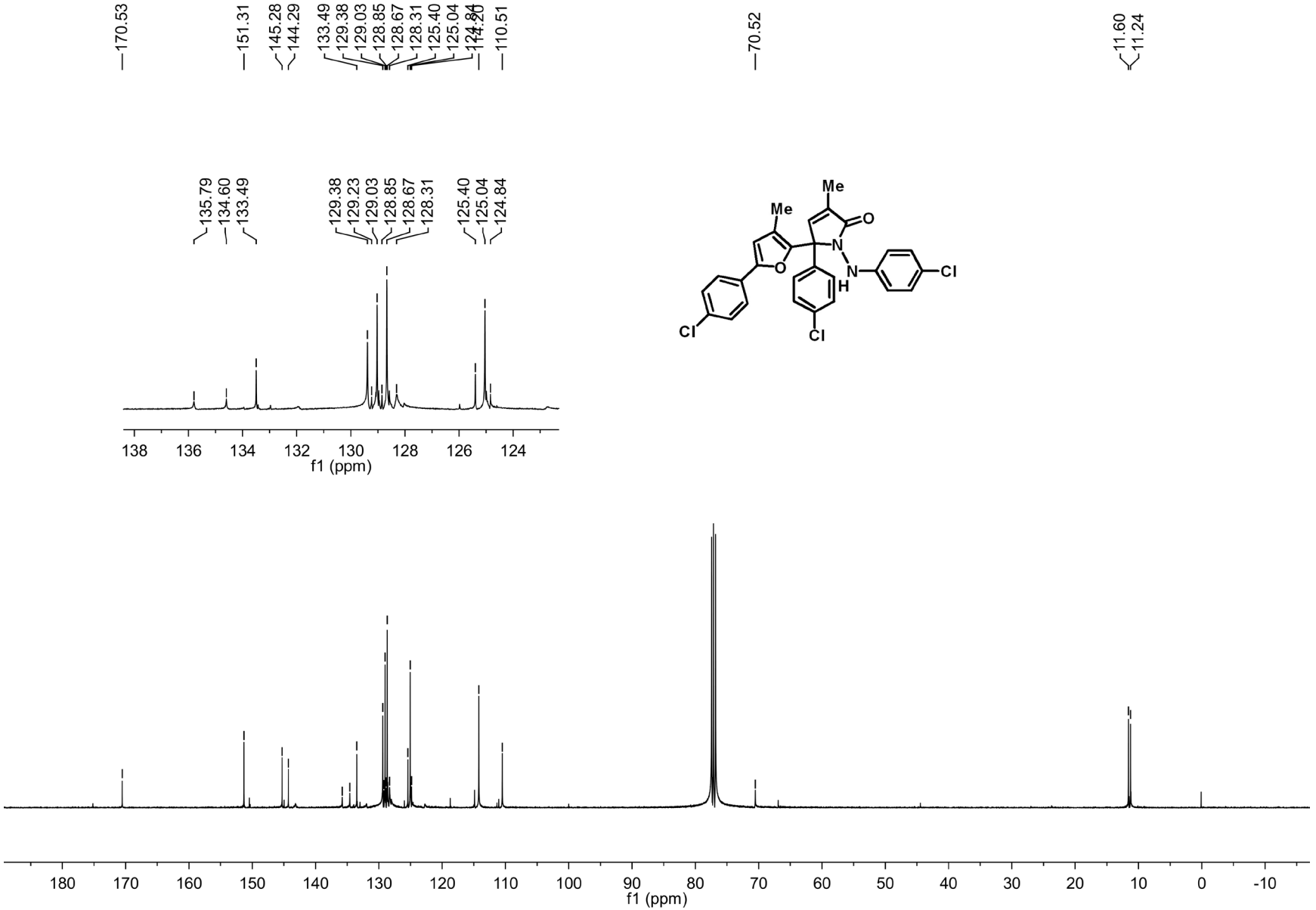
^{1}H NMR Spectrum of Compound **3u**



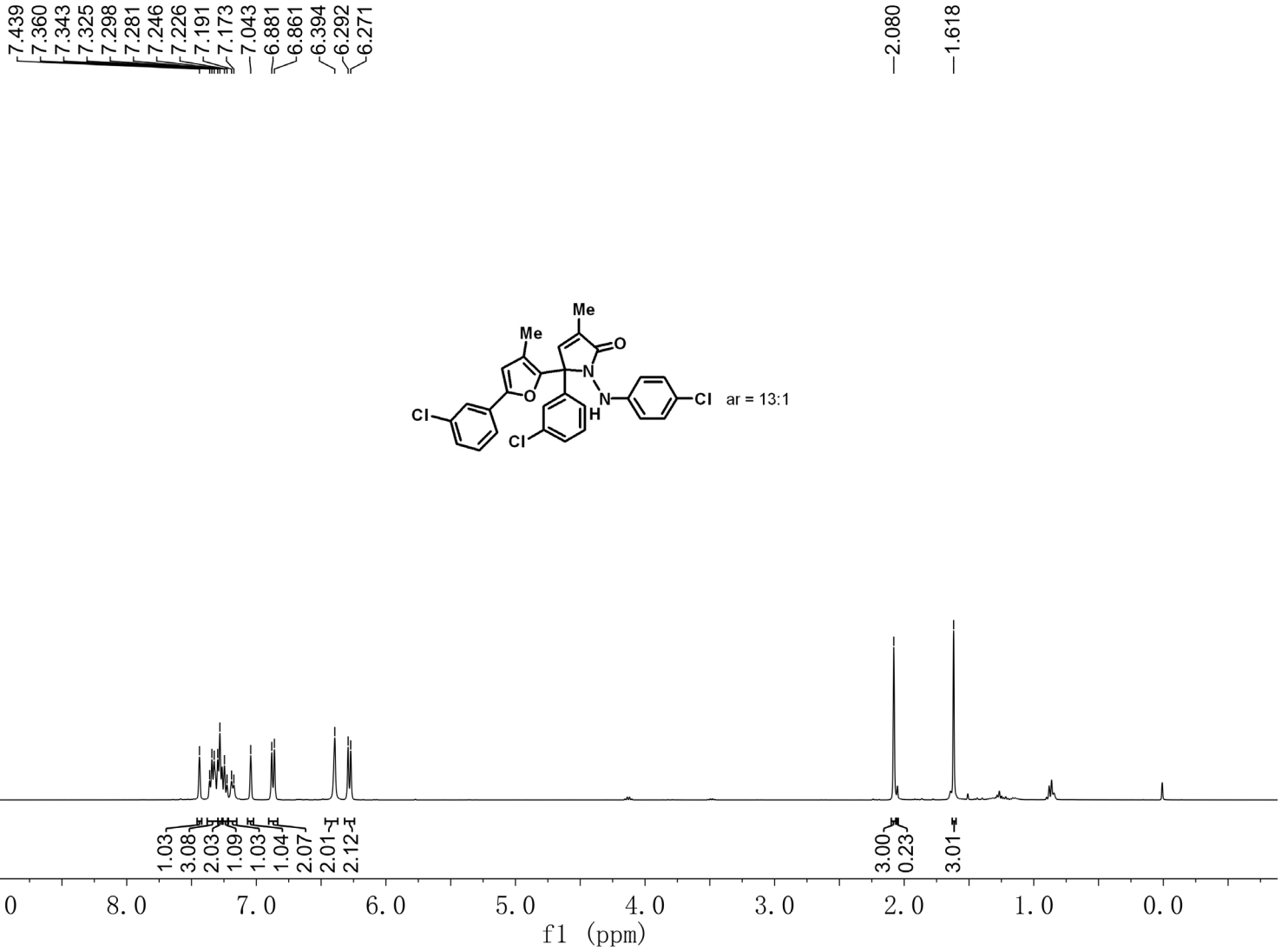
^{13}C NMR Spectrum of Compound **3u**



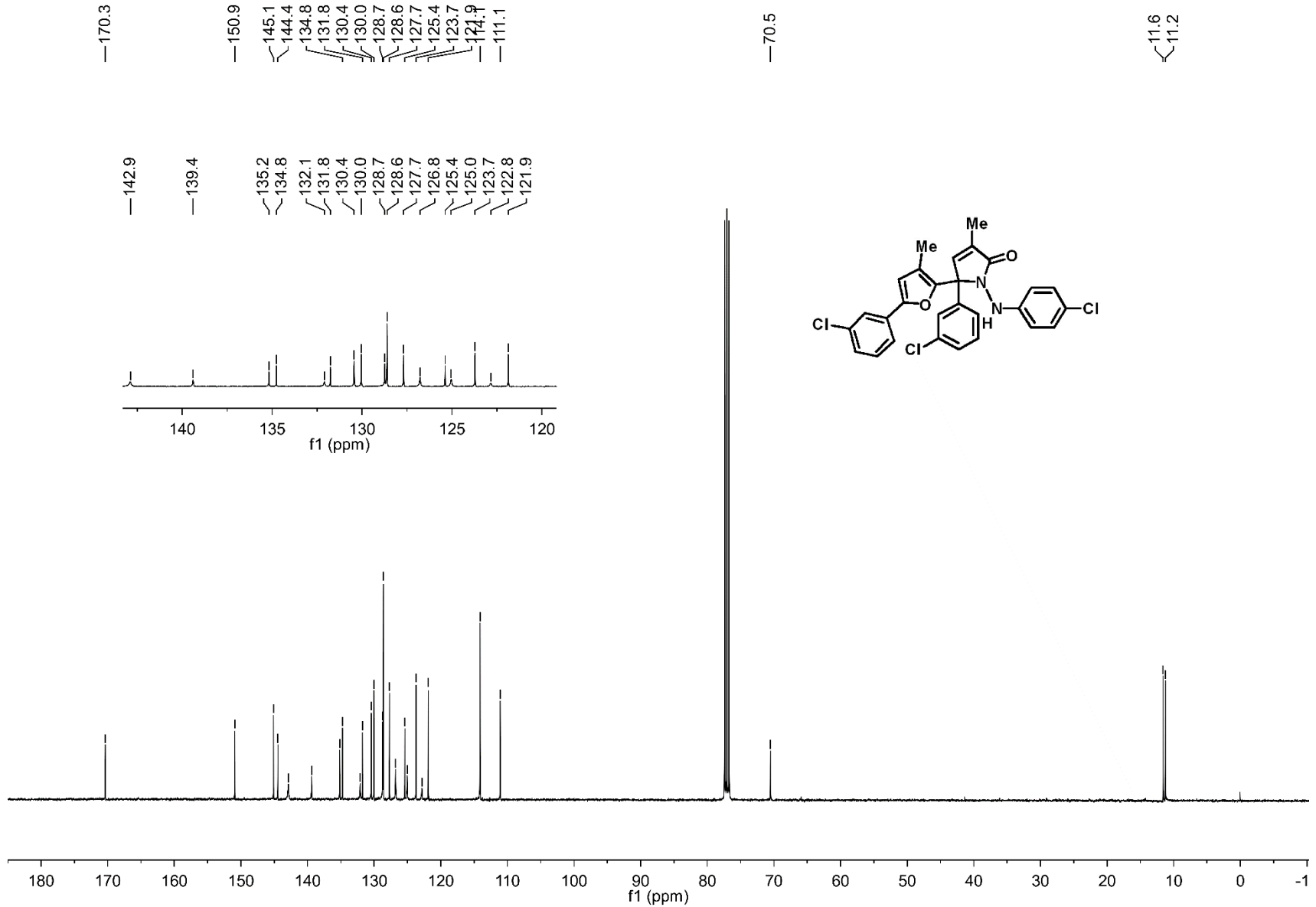
^{1}H NMR Spectrum of Compound **3v**



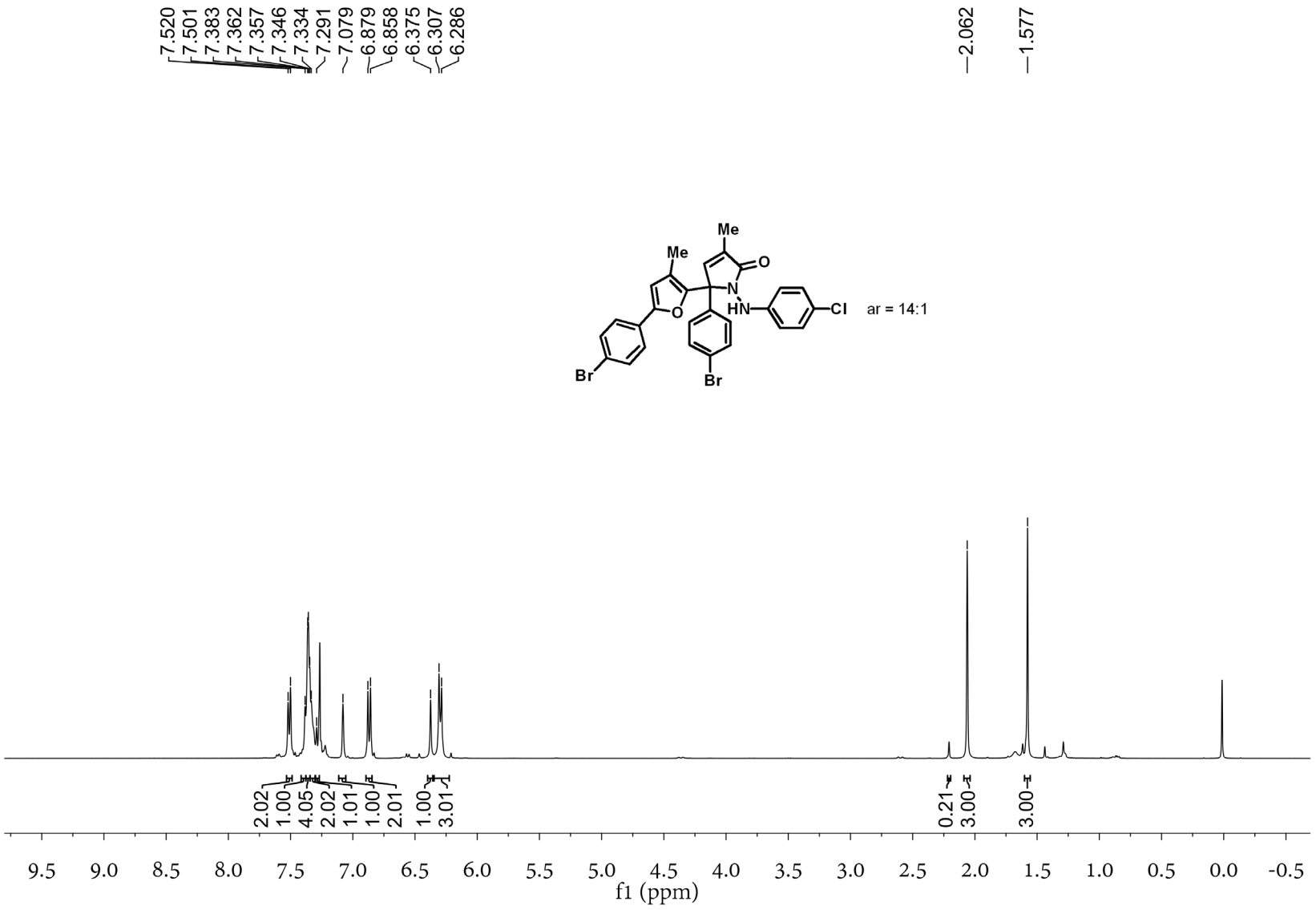
^{13}C NMR Spectrum of Compound **3v**



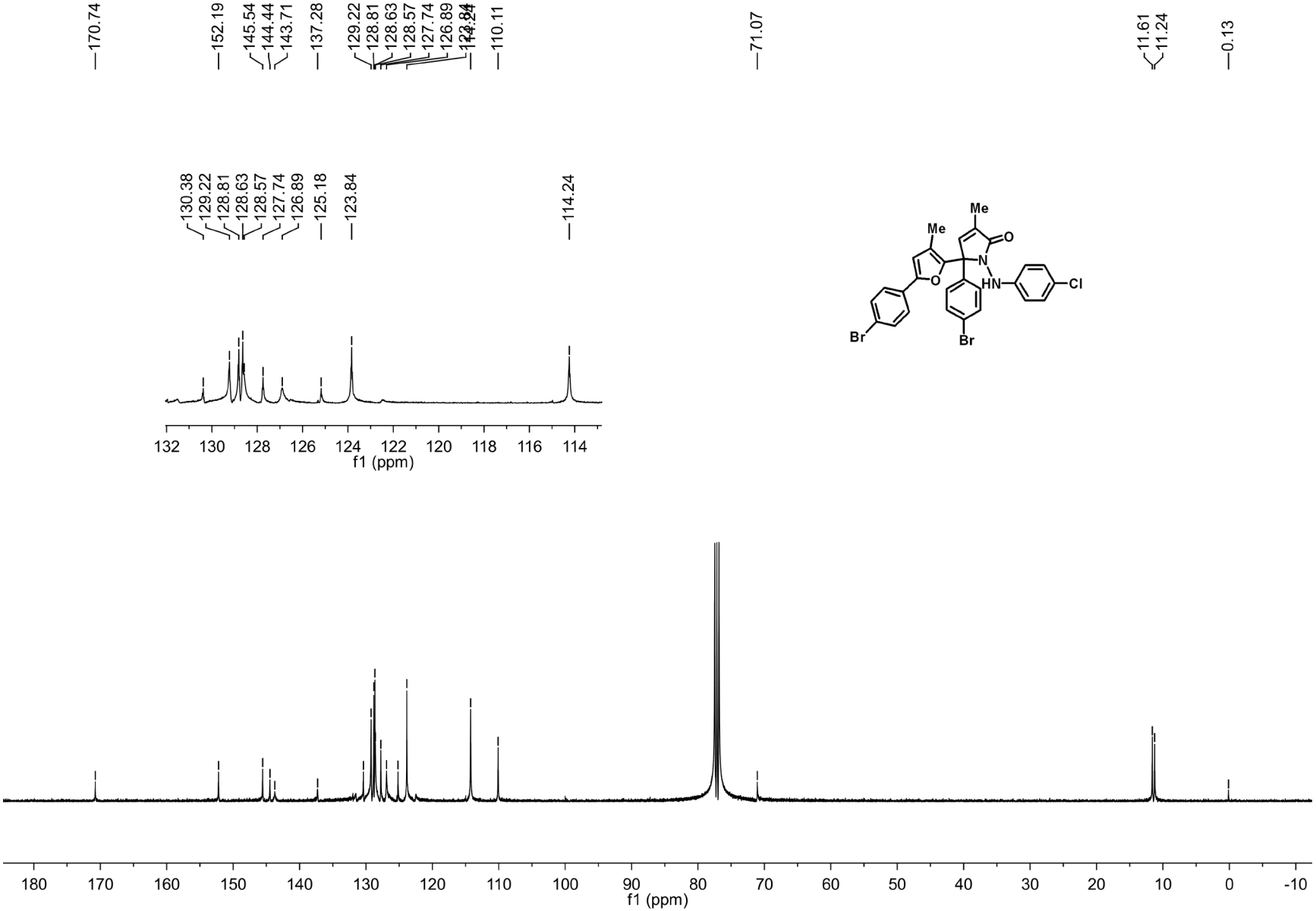
^{1}H NMR Spectrum of Compound **3w**



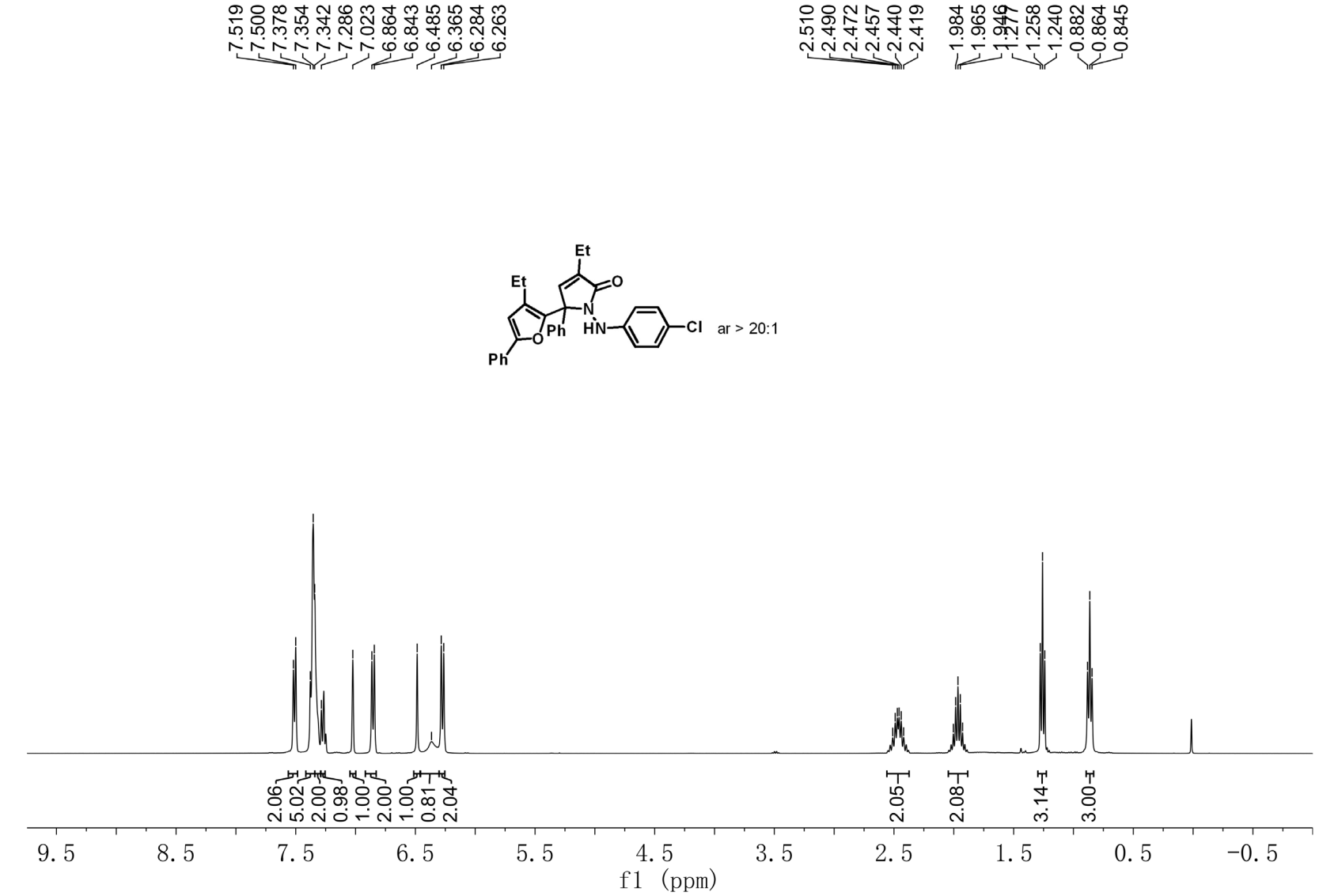
^{13}C NMR Spectrum of Compound **3w**



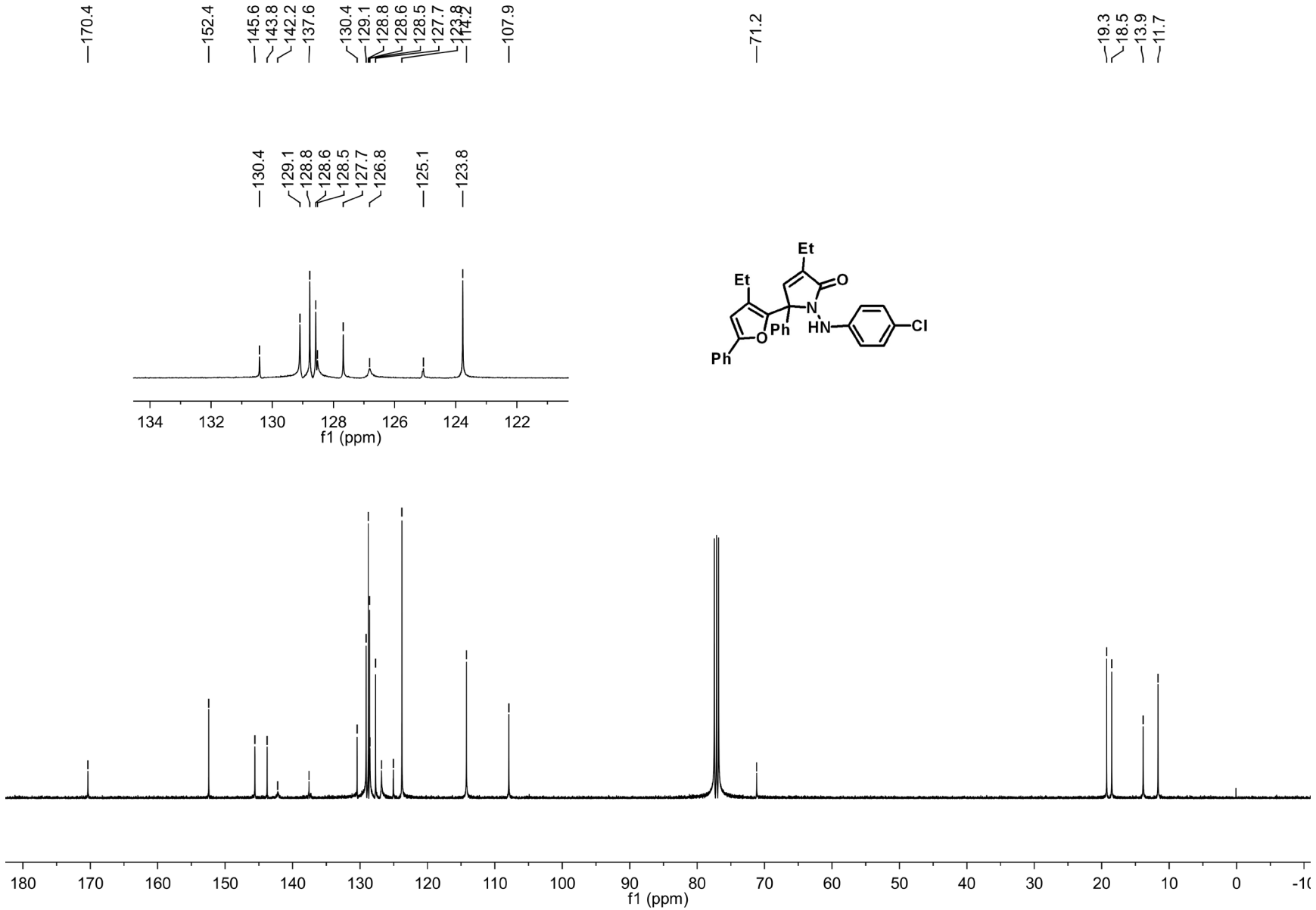
^{1}H NMR Spectrum of Compound **3x**



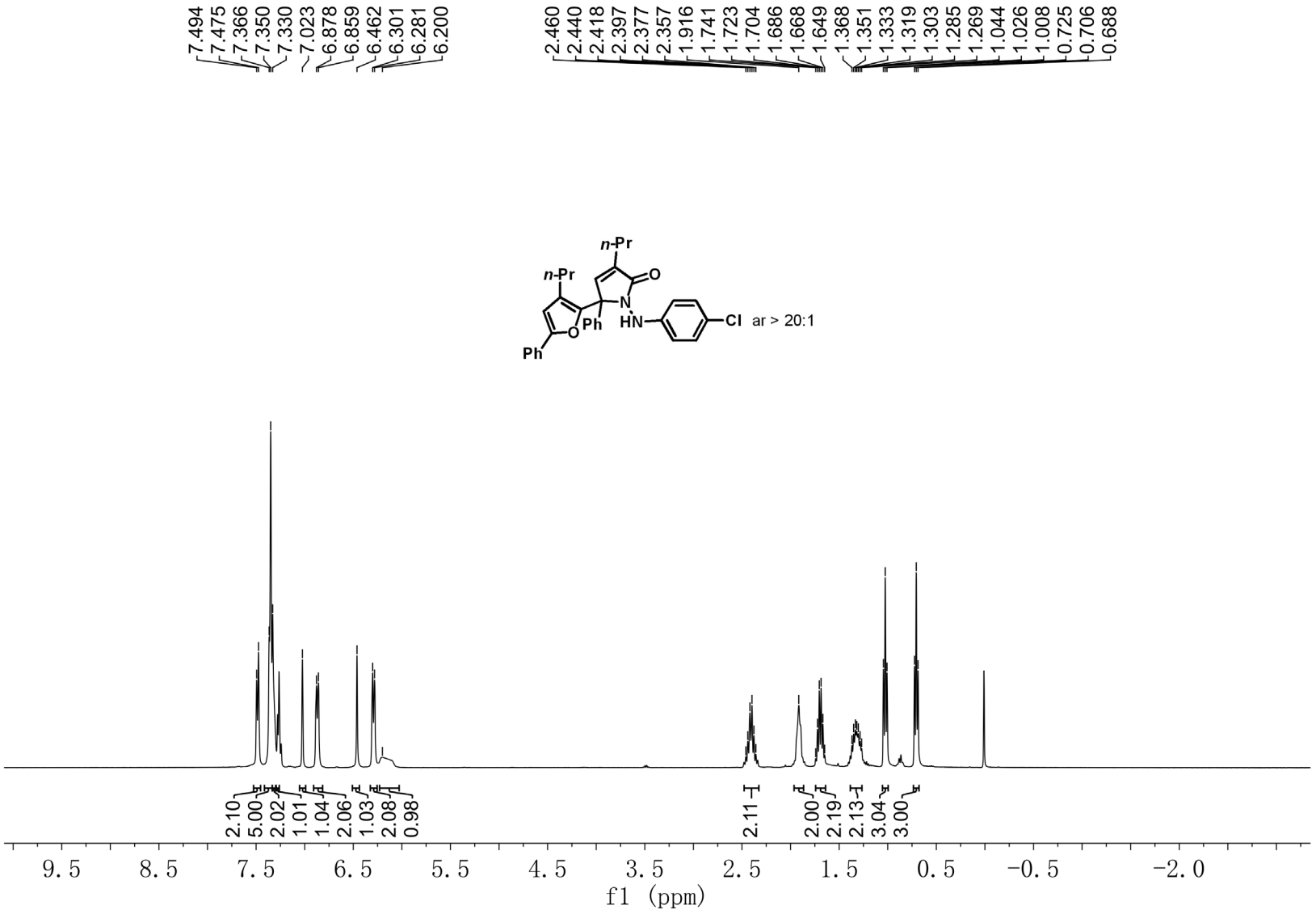
^{13}C NMR Spectrum of Compound **3x**



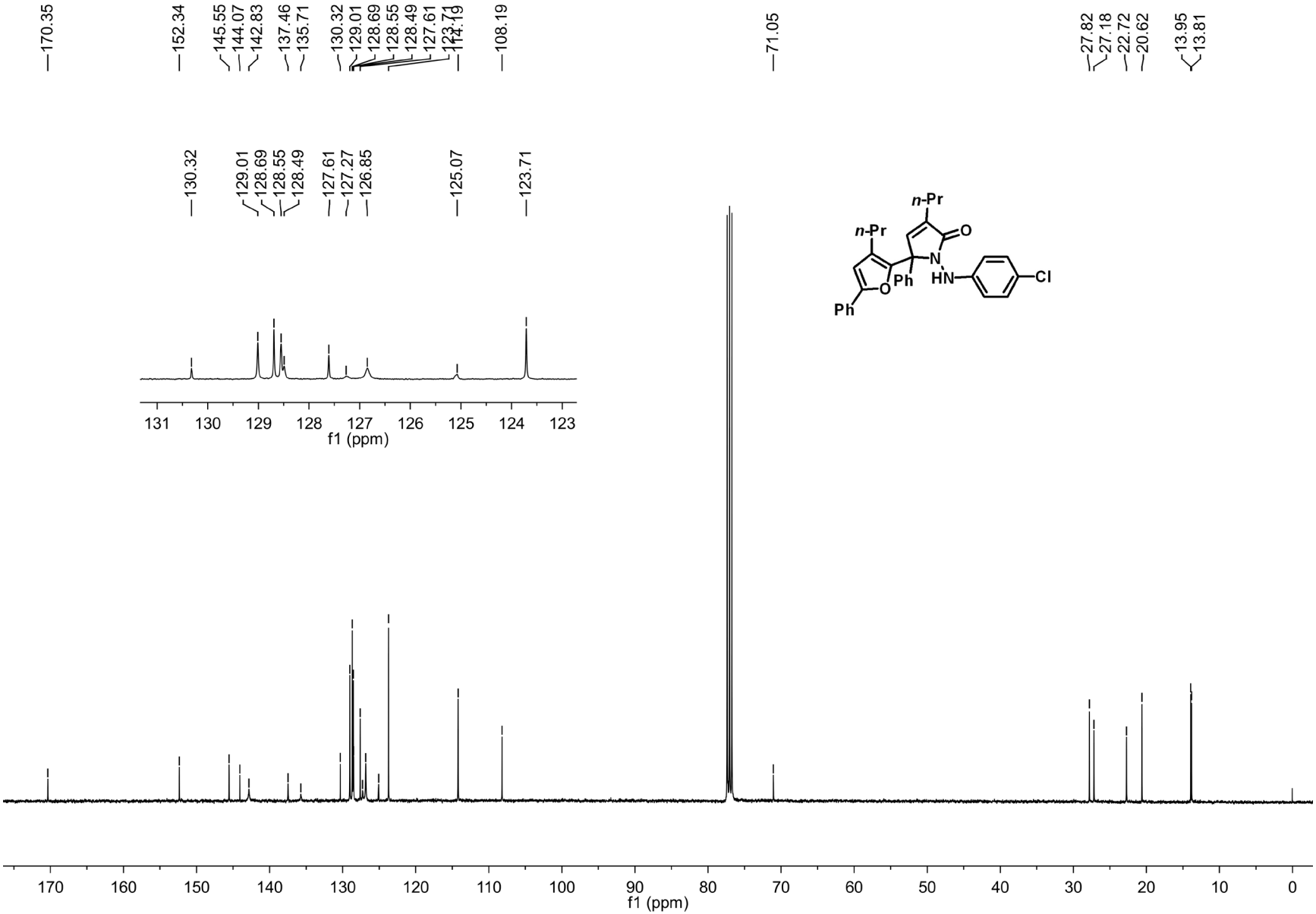
^{1}H NMR Spectrum of Compound **3aa**



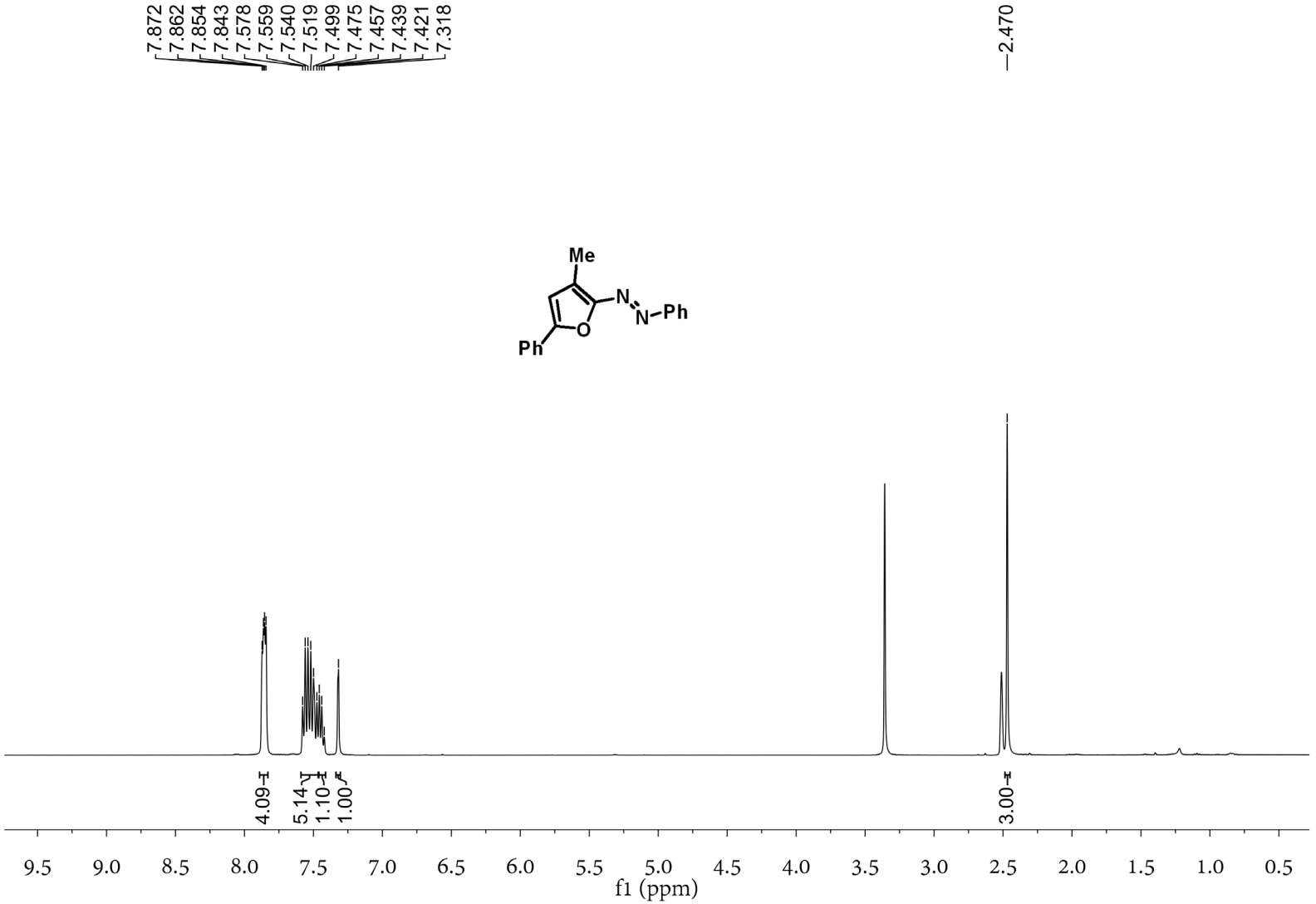
^{13}C NMR Spectrum of Compound **3aa**



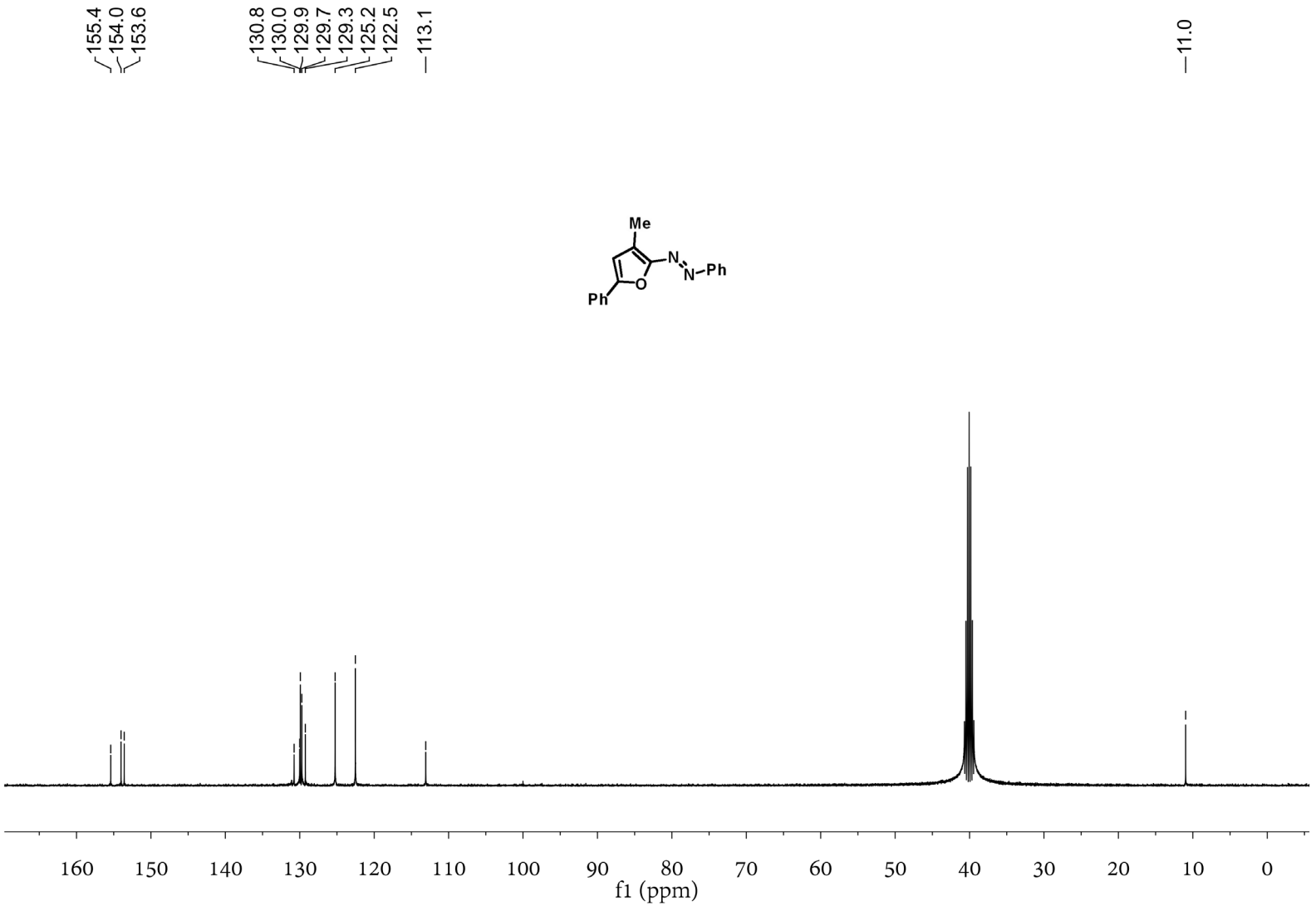
^{1}H NMR Spectrum of Compound **3bb**



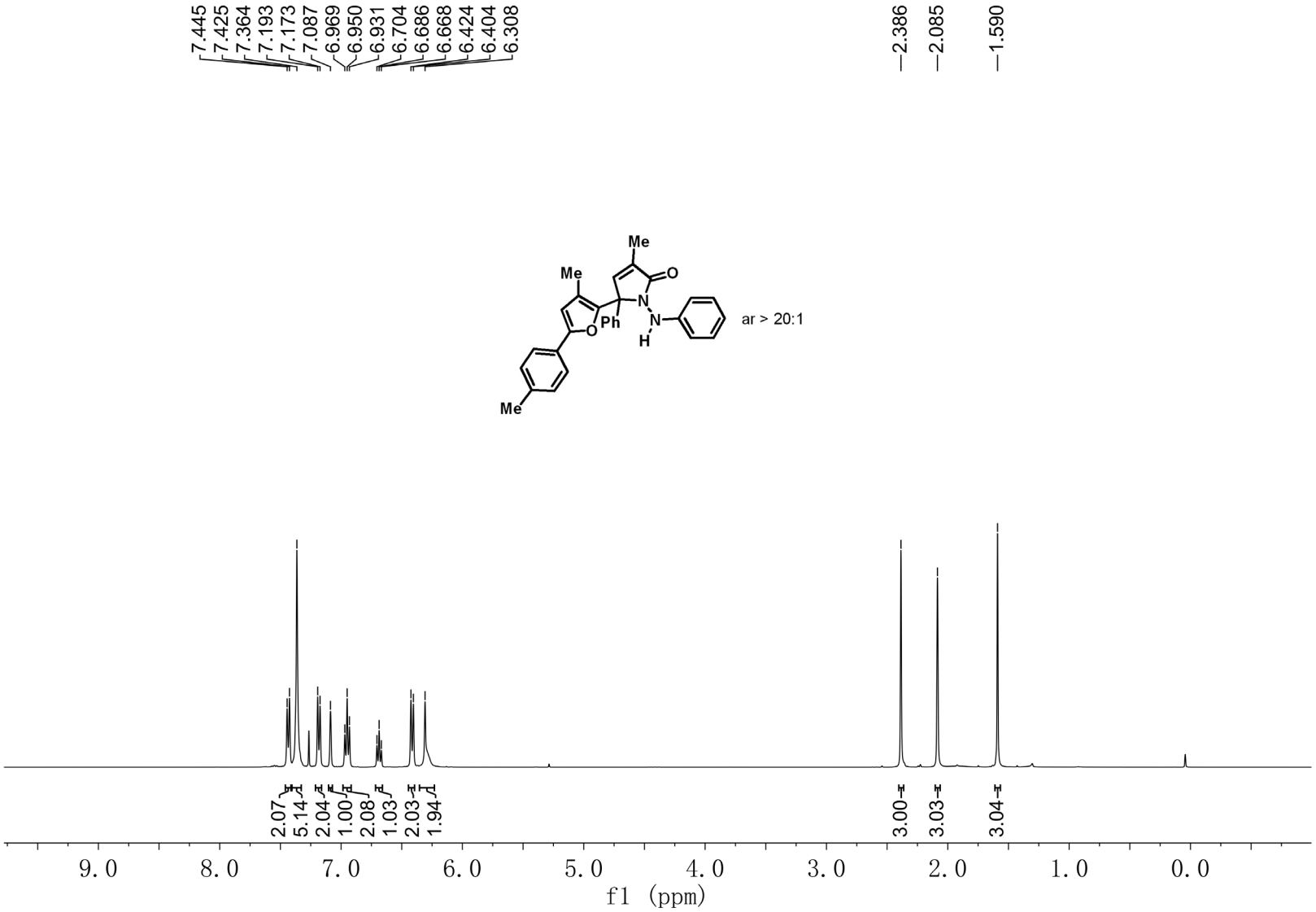
^{13}C NMR Spectrum of Compound **3bb**



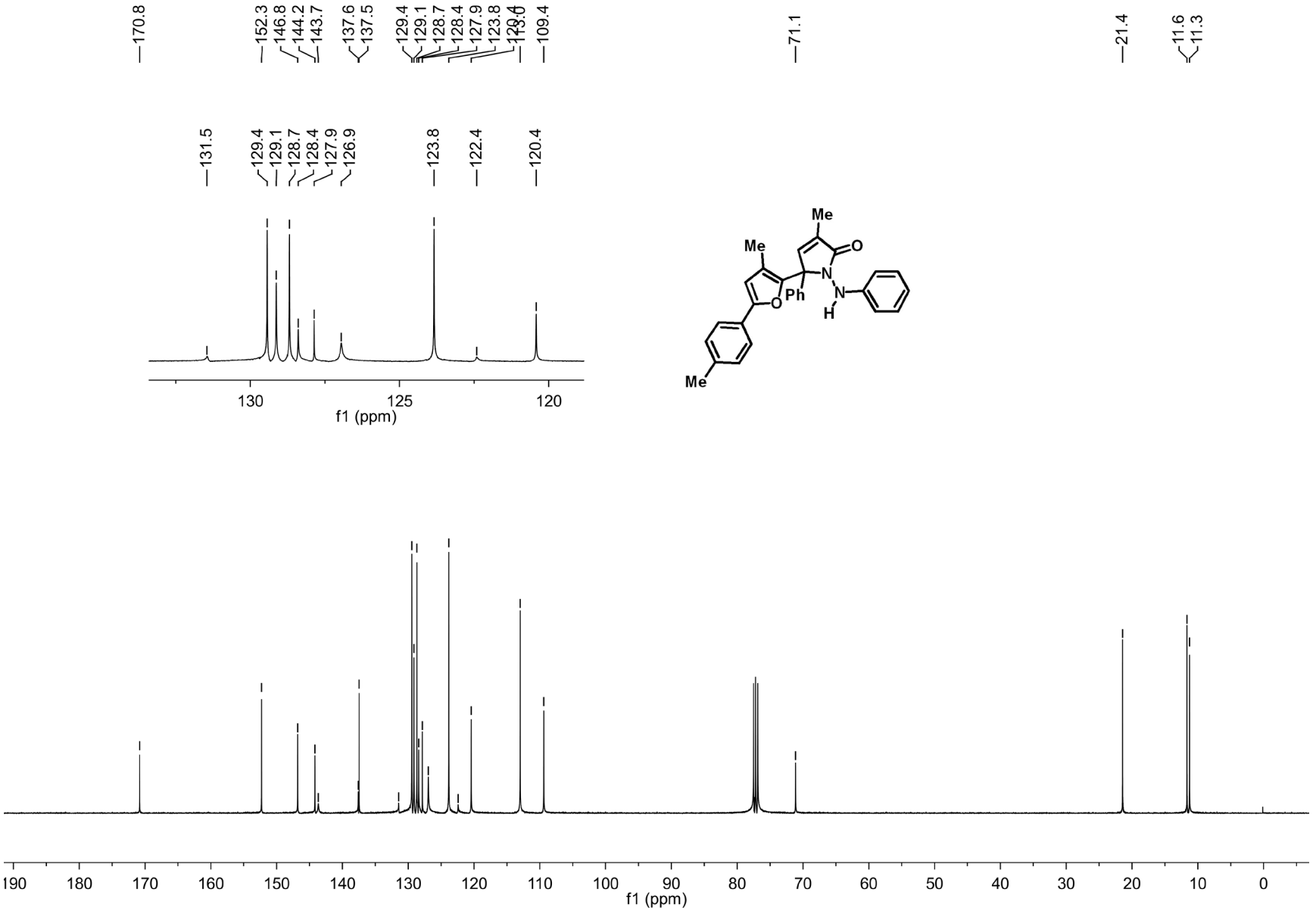
^{1}H NMR Spectrum of Compound **4**



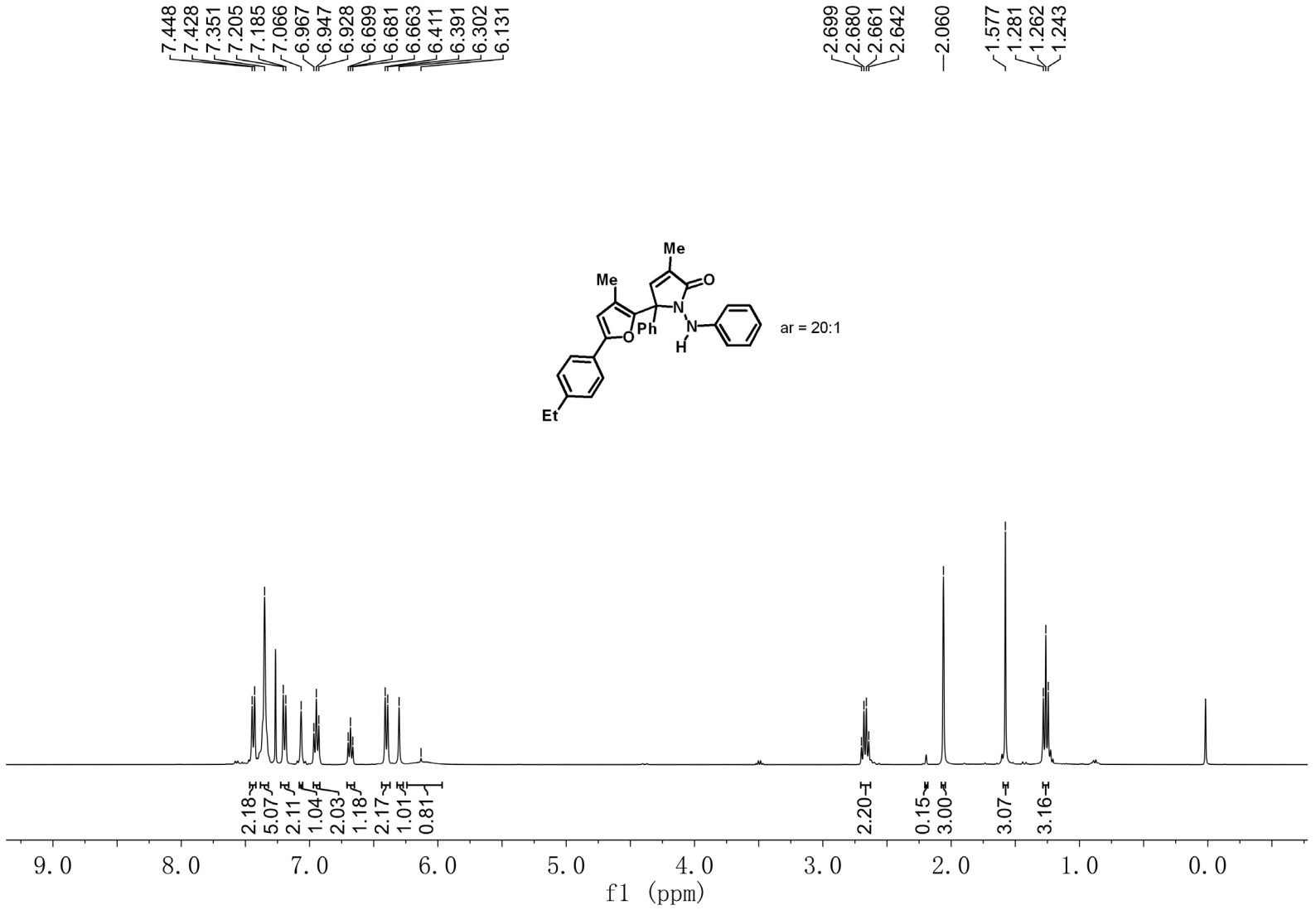
^{13}C NMR Spectrum of Compound **4**



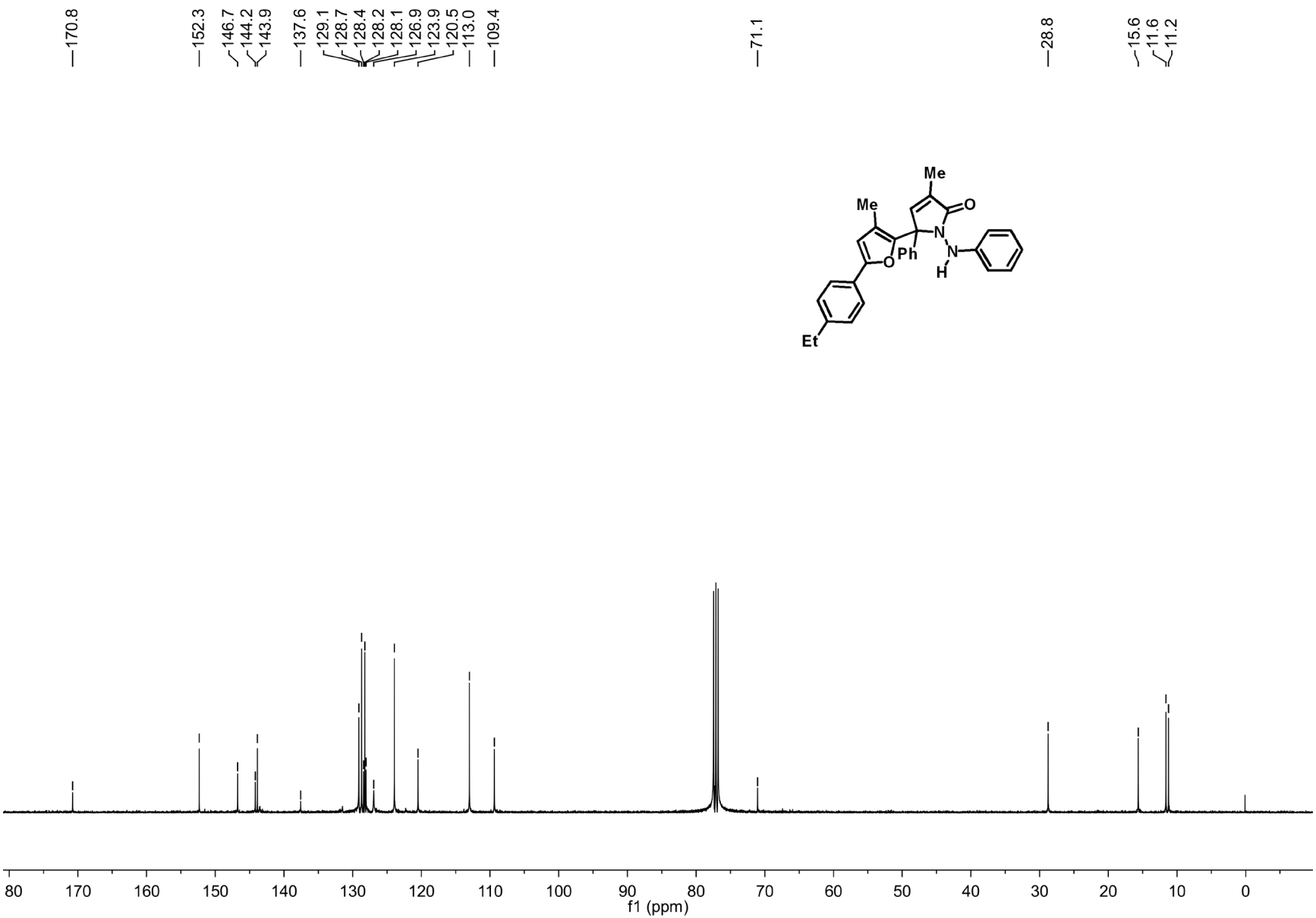
^{1}H NMR Spectrum of Compound **5a**



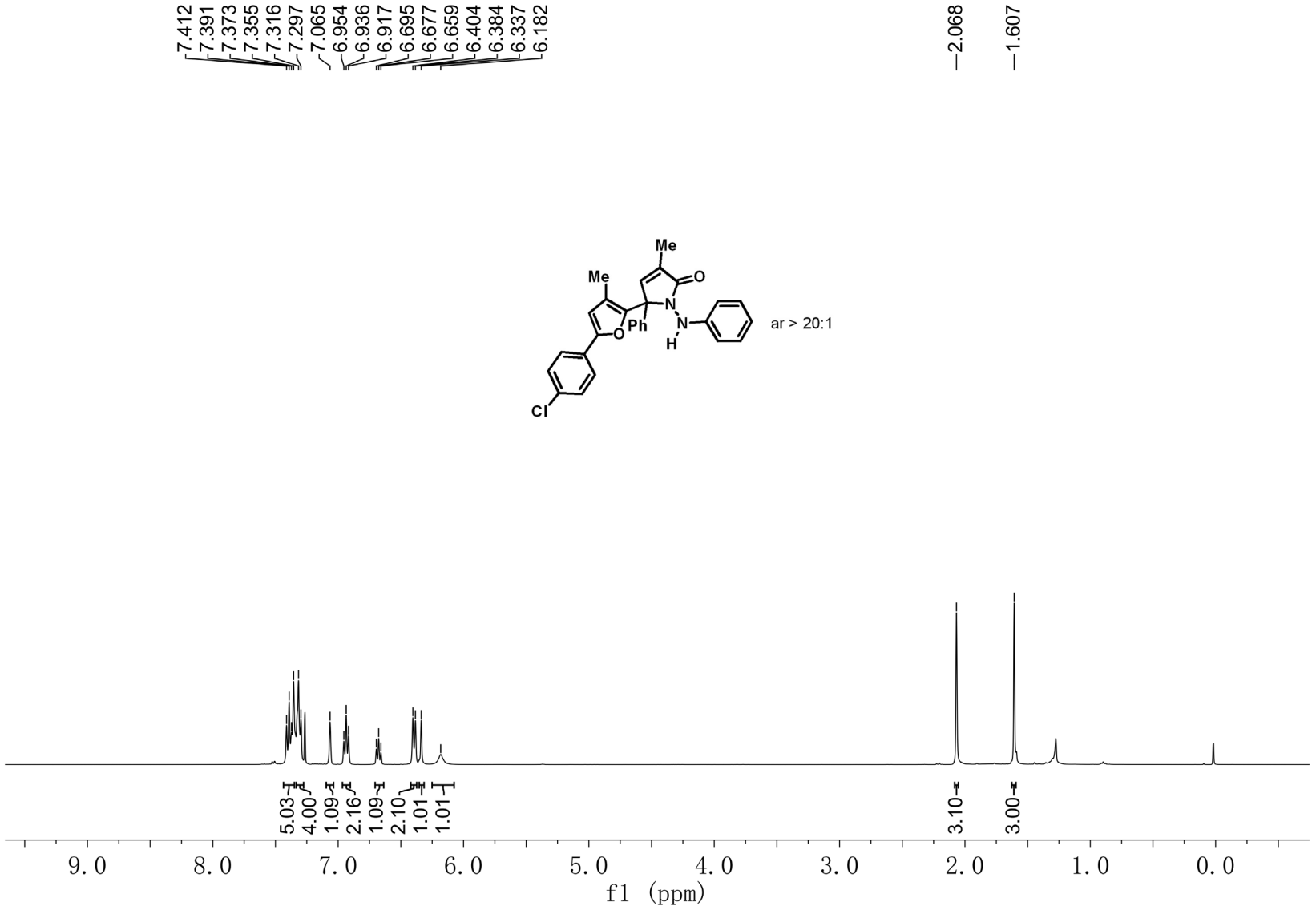
^{13}C NMR Spectrum of Compound **5a**



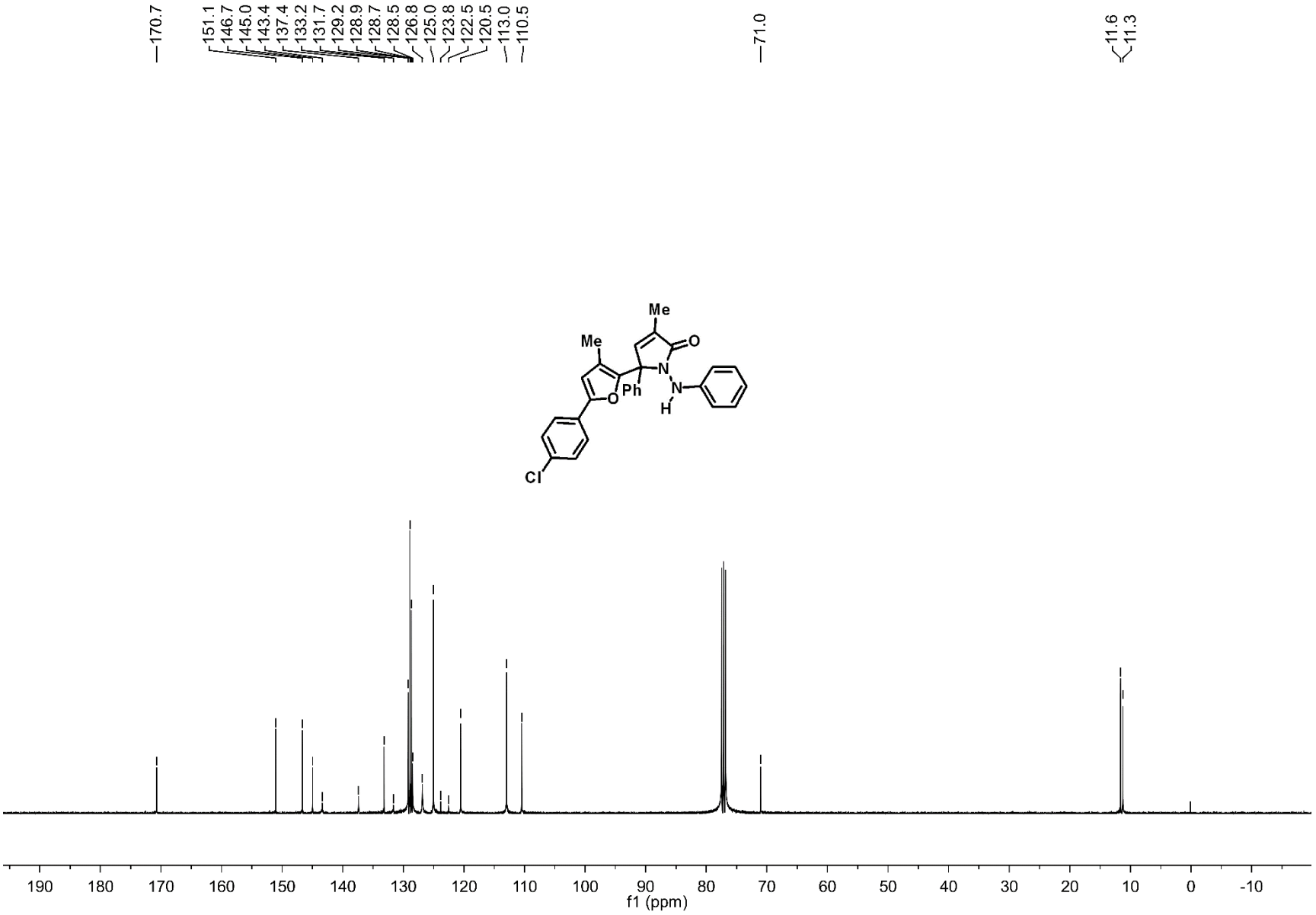
^{1}H NMR Spectrum of Compound **5b**



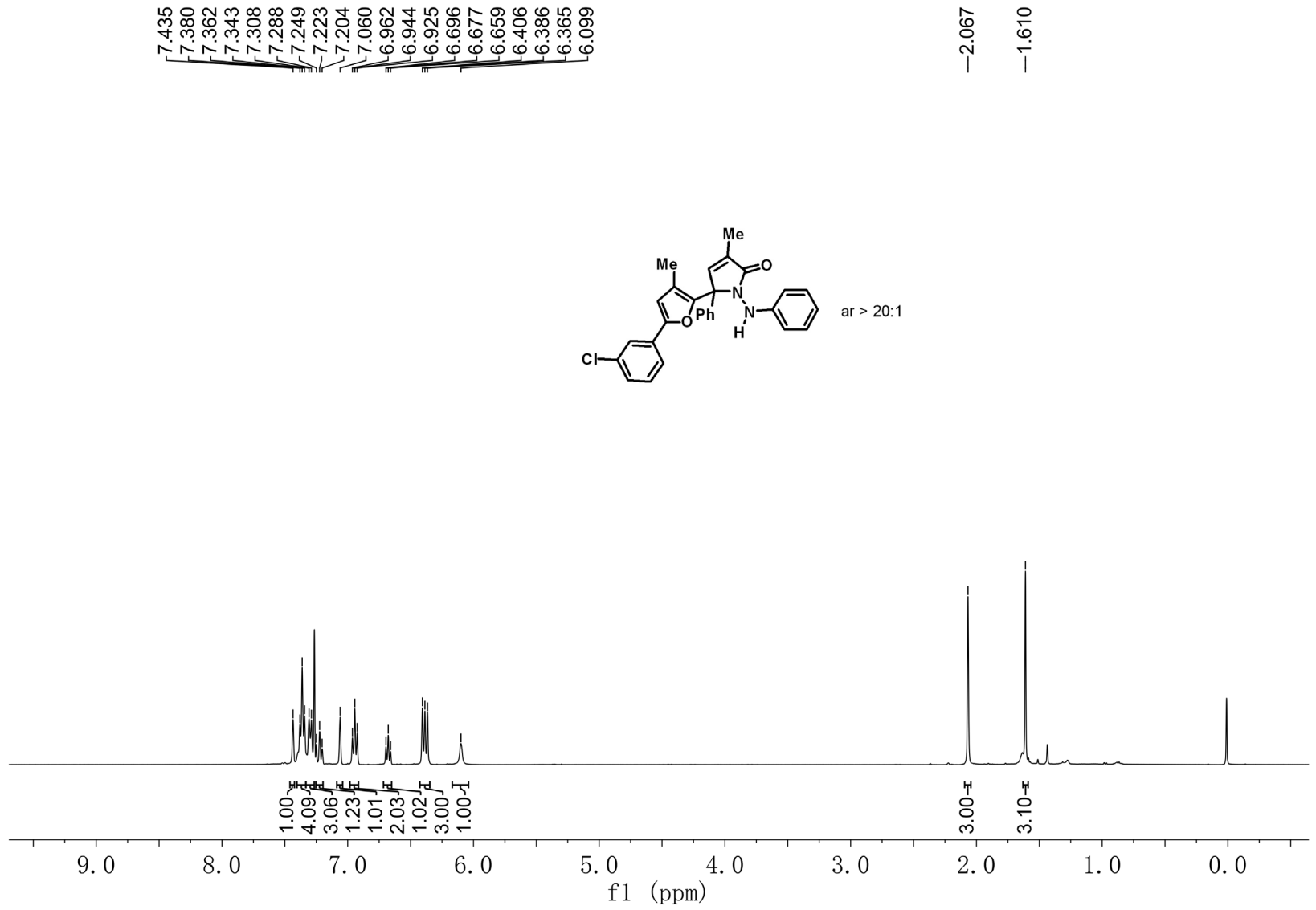
^{13}C NMR Spectrum of Compound **5b**



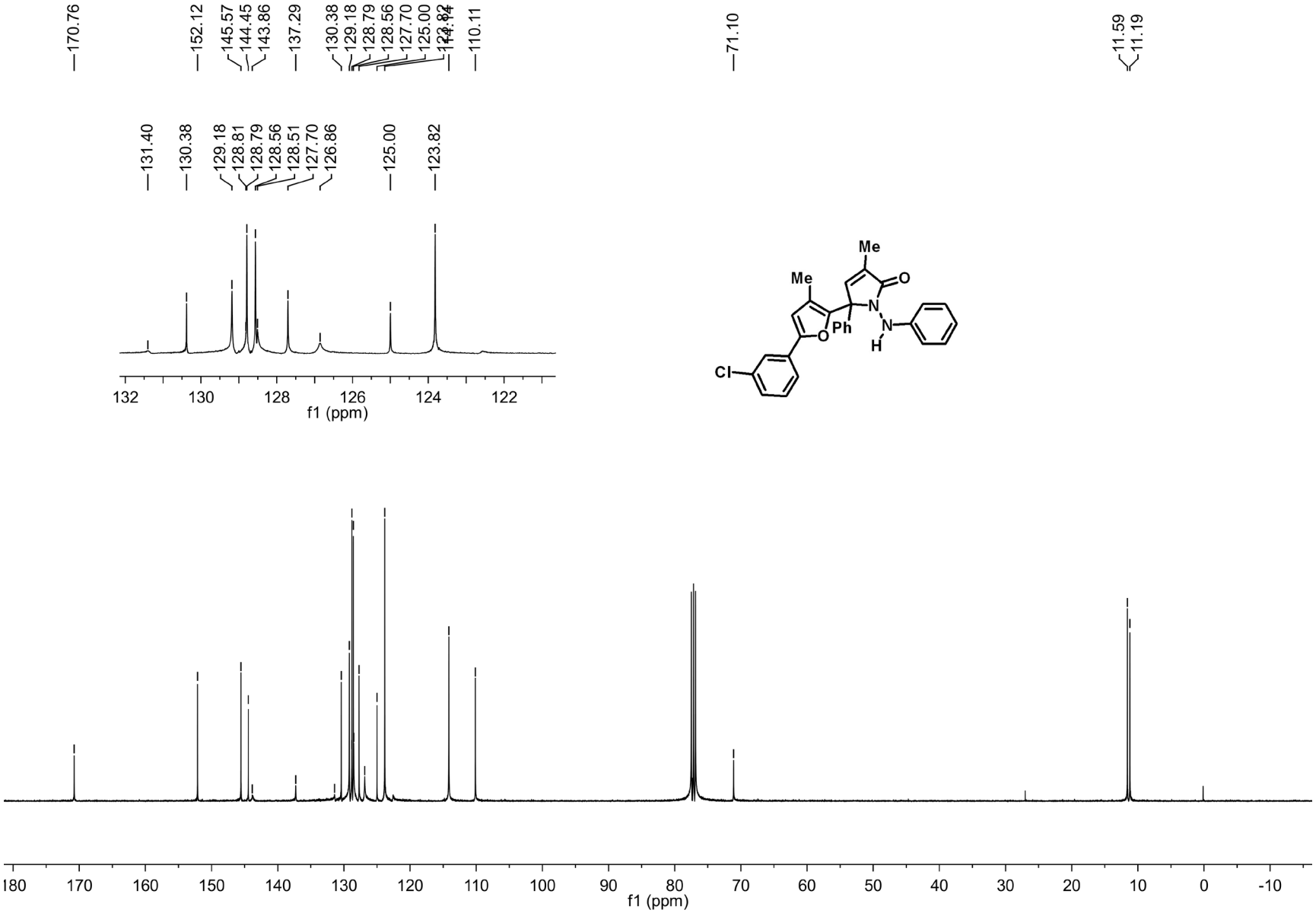
^{1}H NMR Spectrum of Compound **5c**



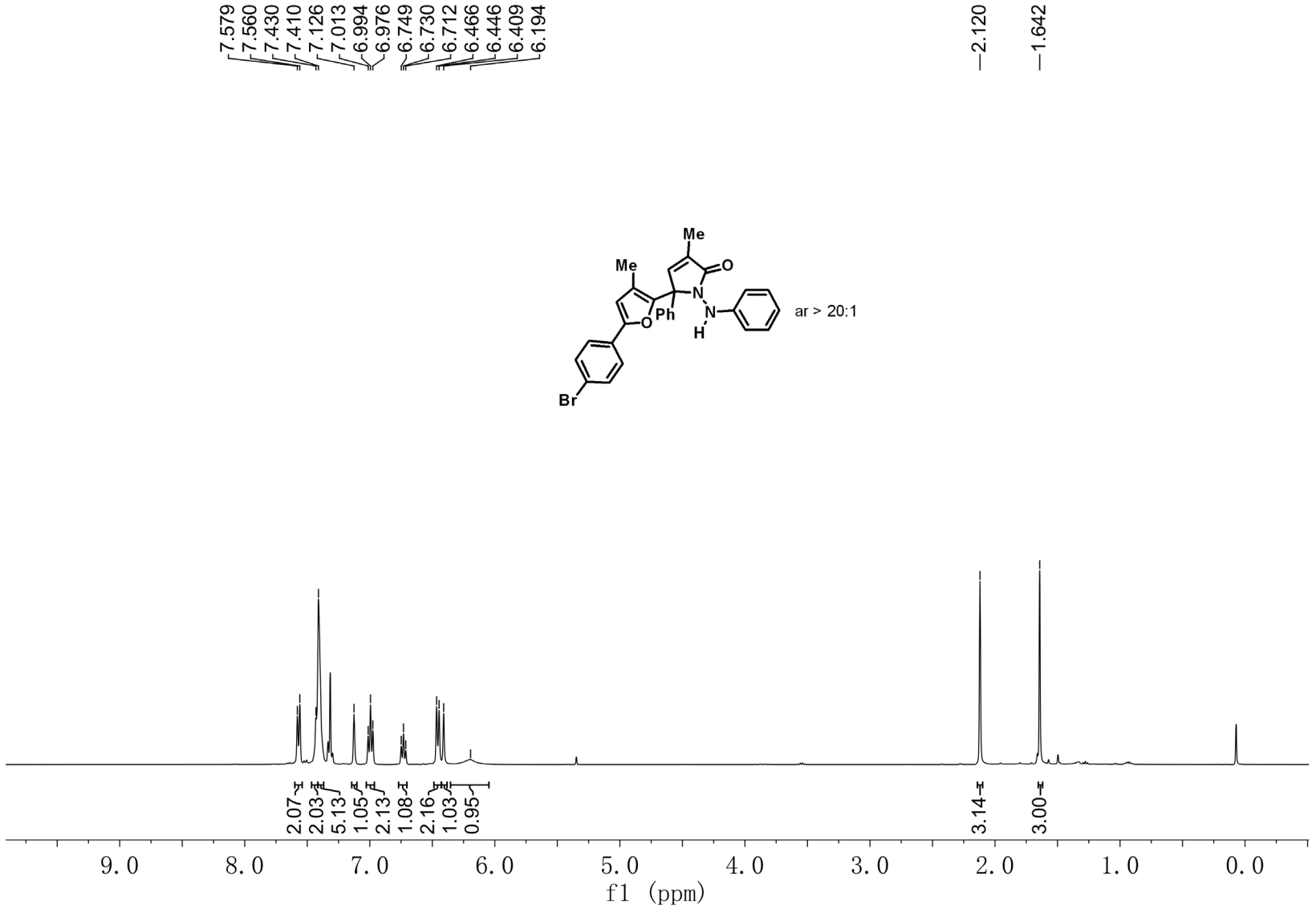
^{13}C NMR Spectrum of Compound **5c**



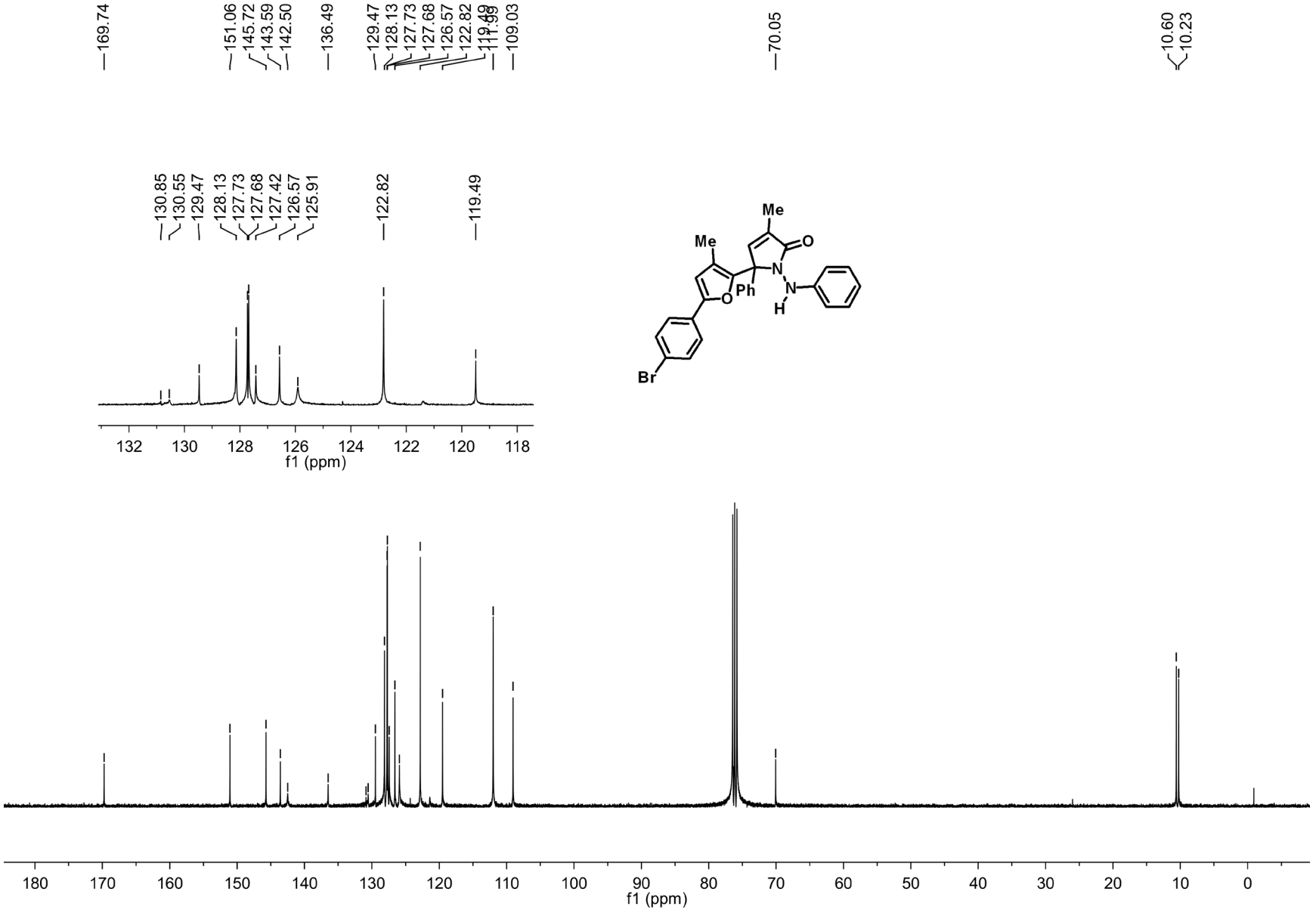
^{1}H NMR Spectrum of Compound **5d**



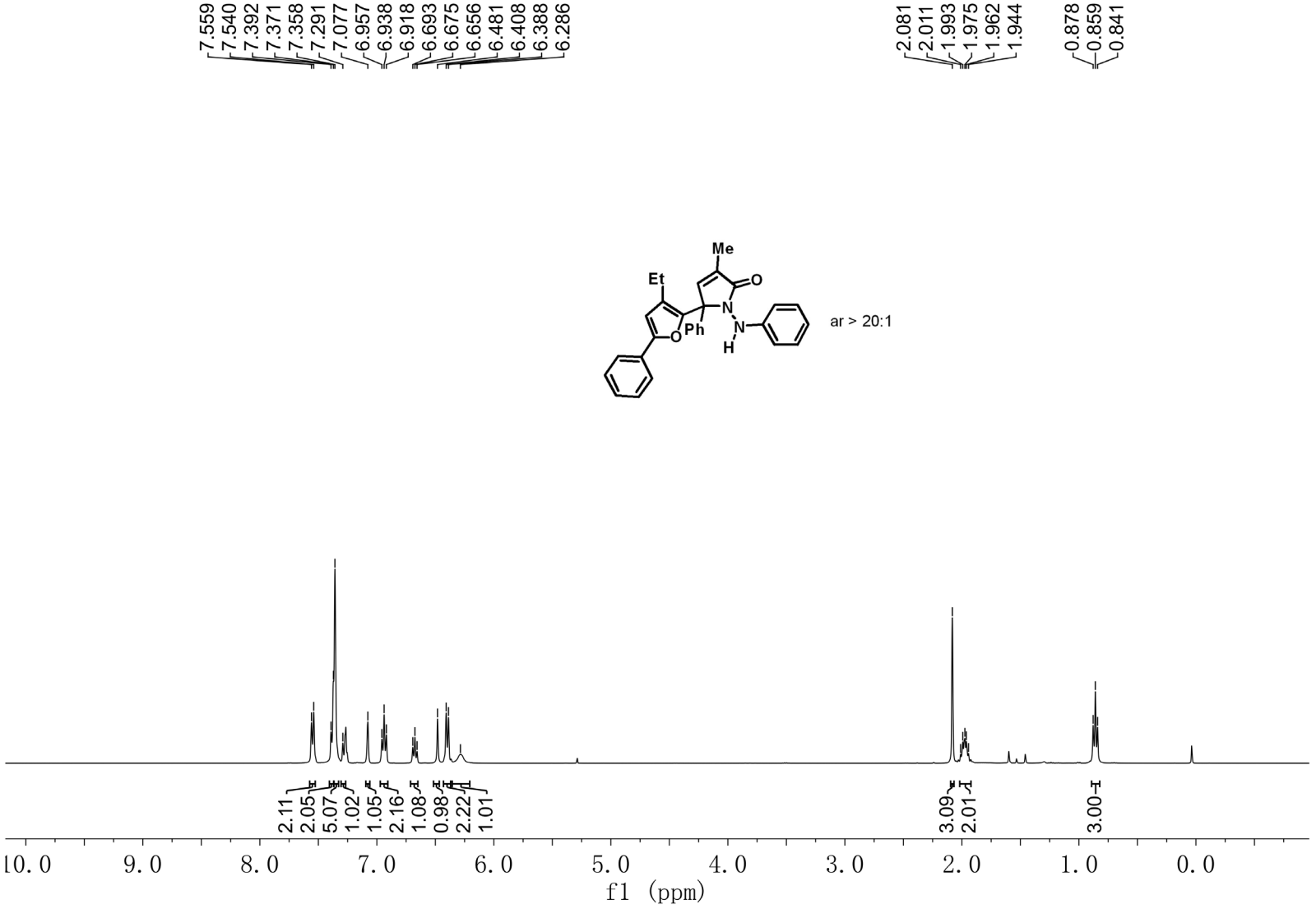
^{13}C NMR Spectrum of Compound **5d**



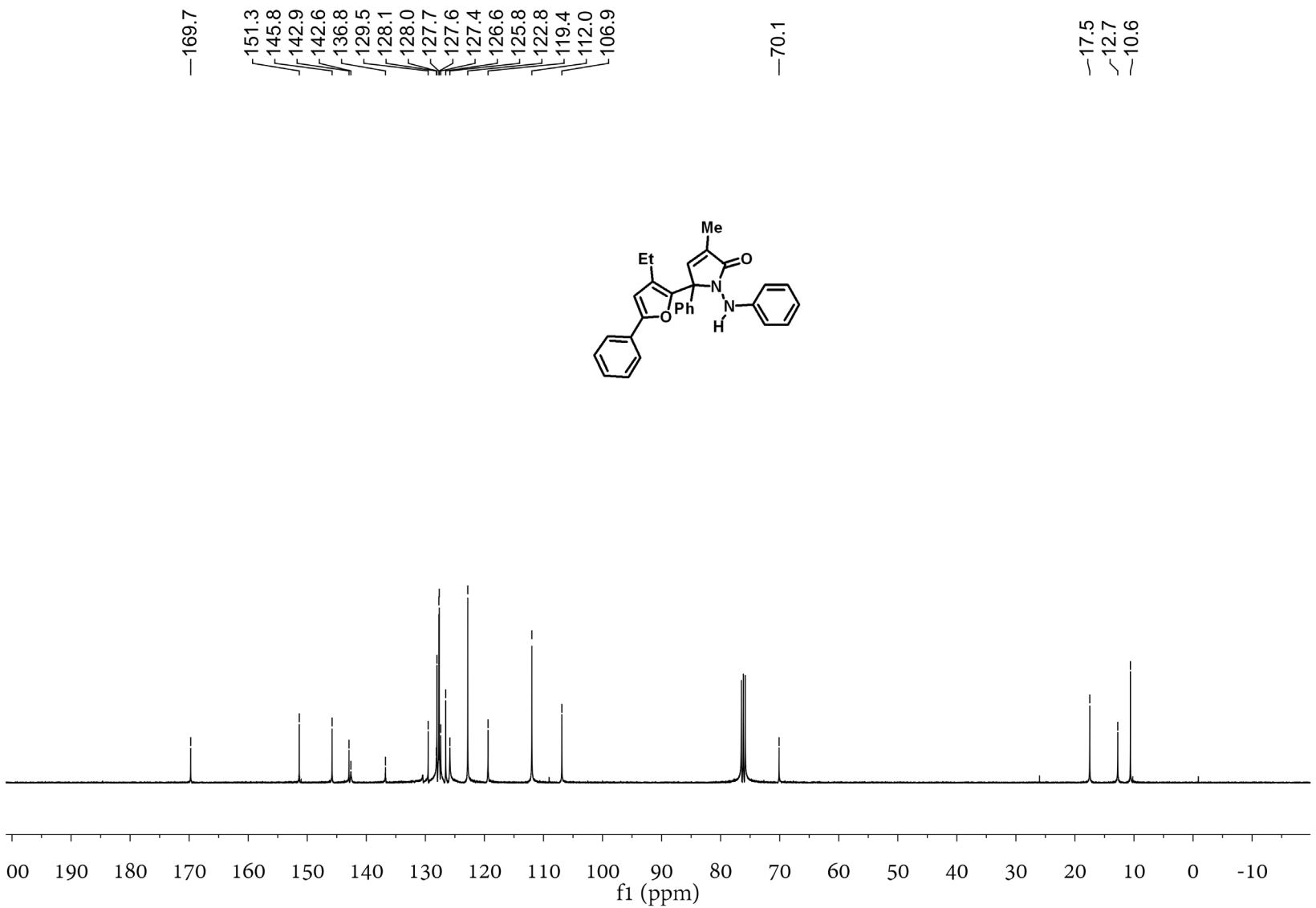
^{1}H NMR Spectrum of Compound **5e**



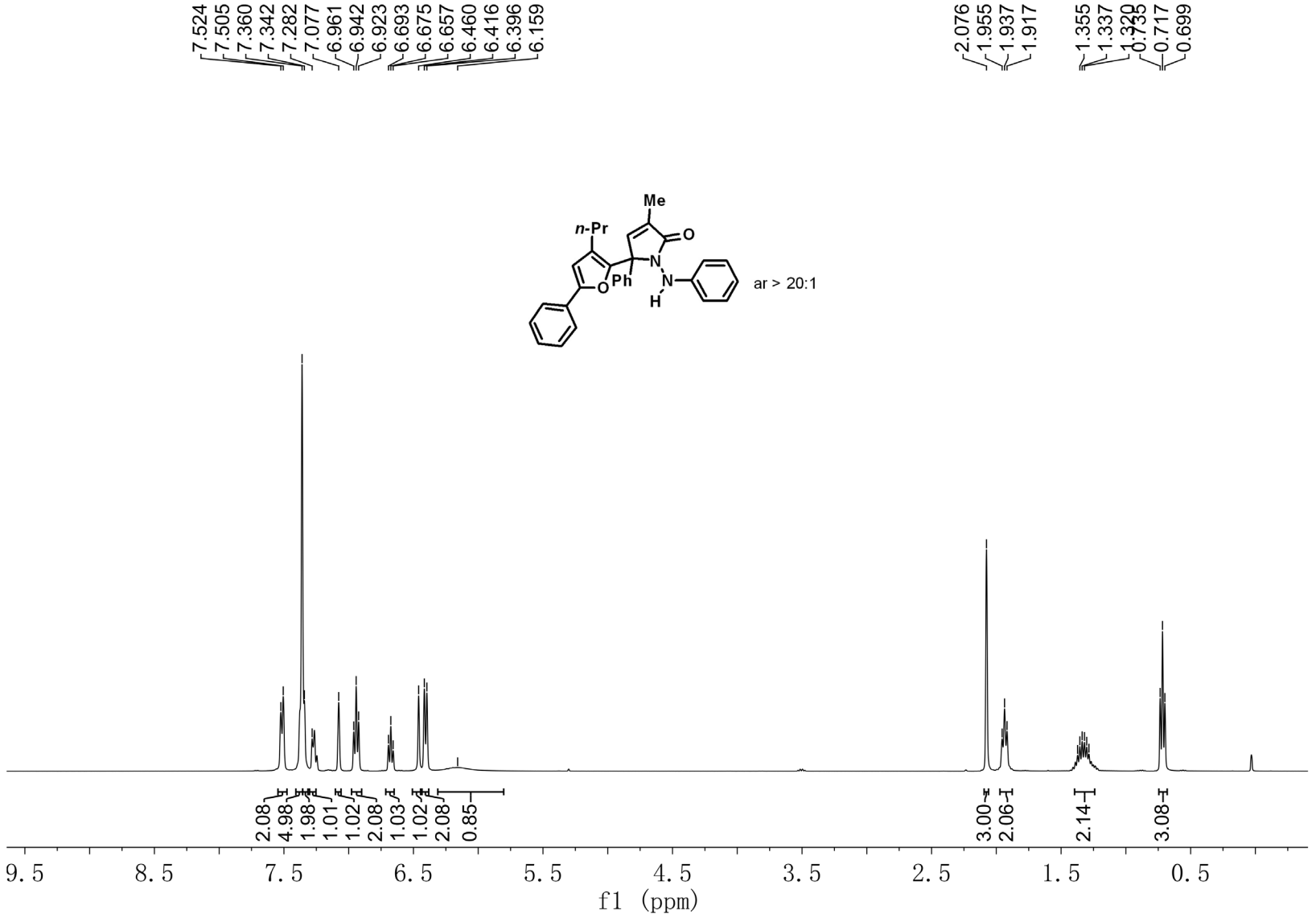
^{13}C NMR Spectrum of Compound **5e**



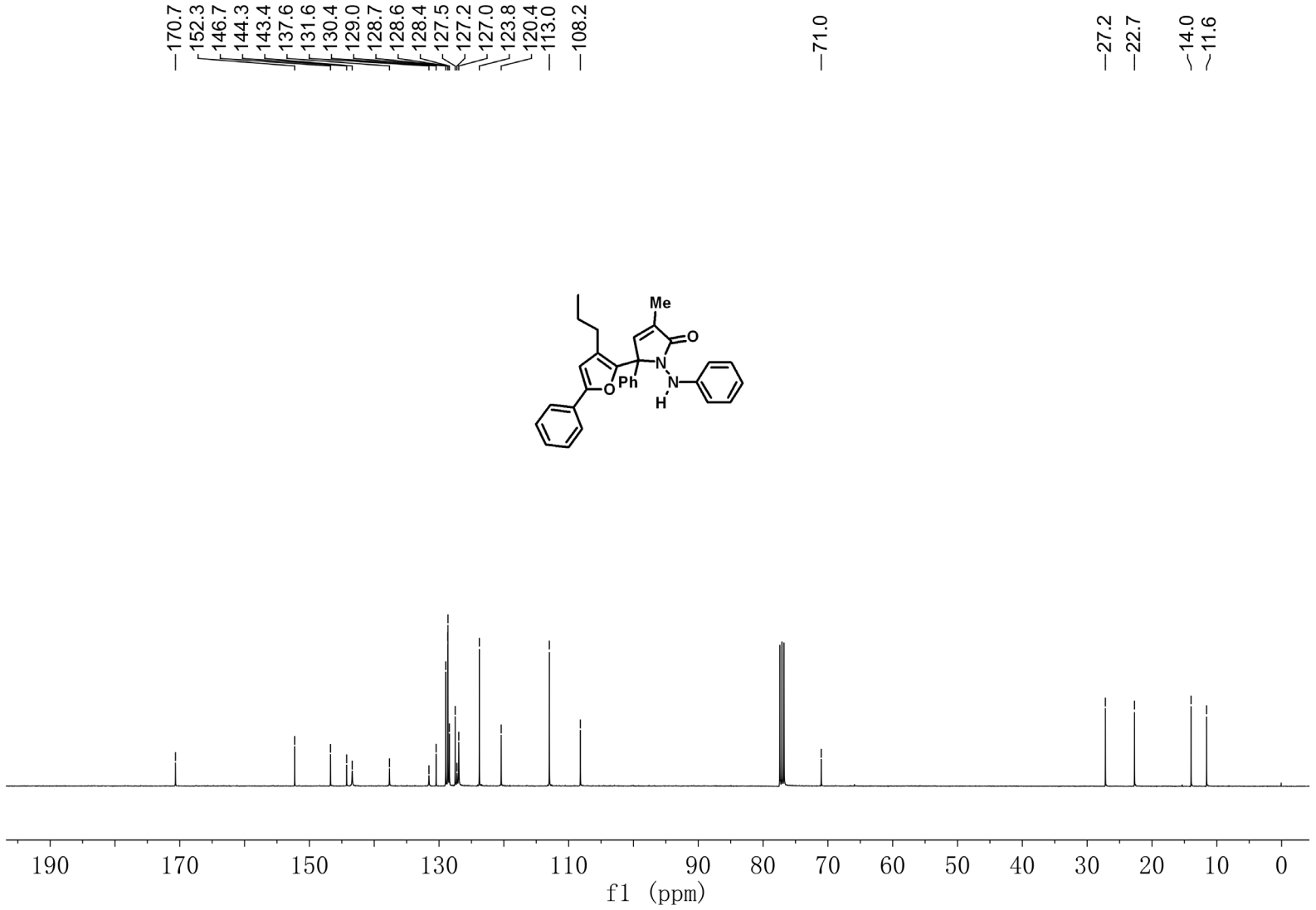
^{1}H NMR Spectrum of Compound **5f**



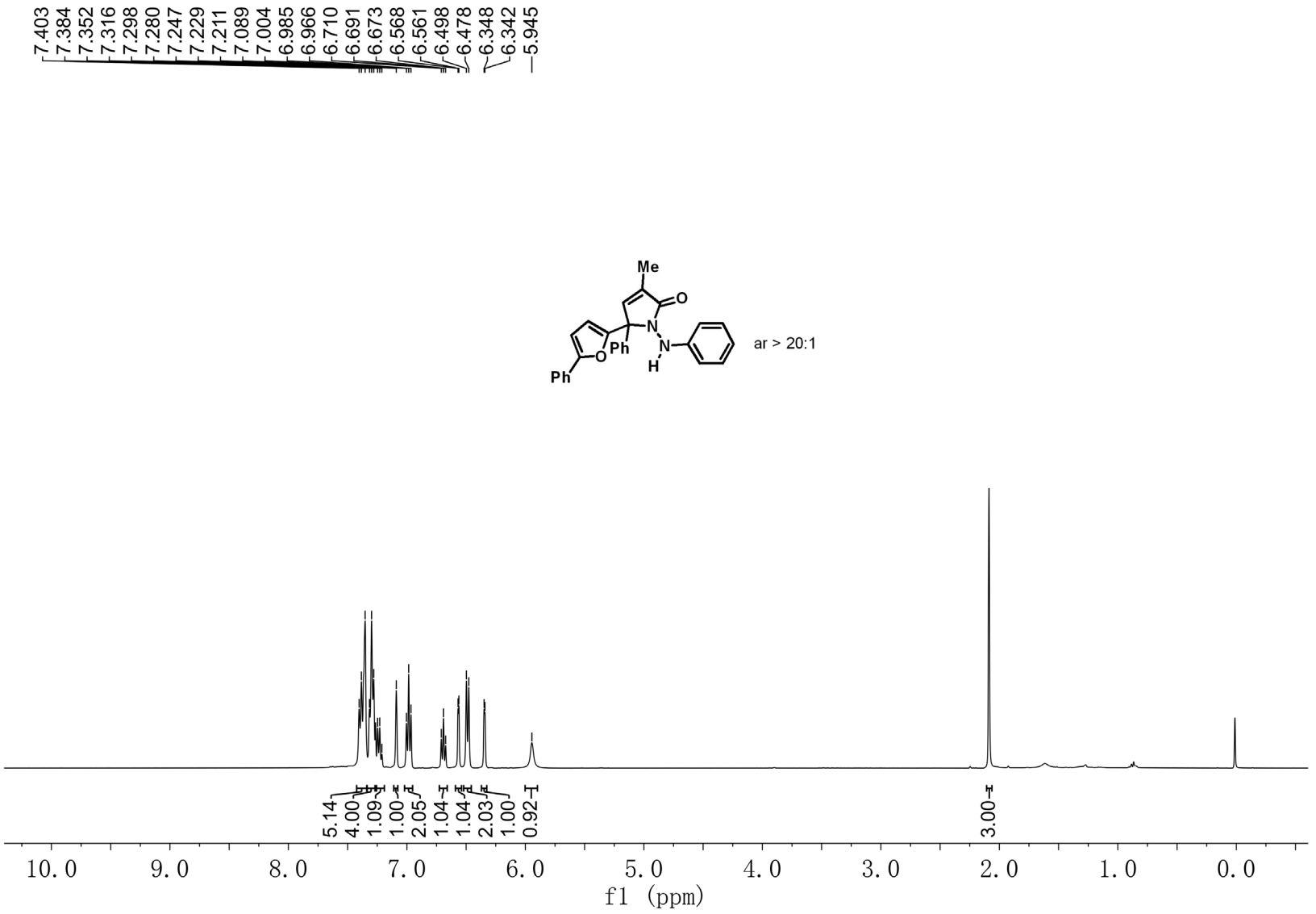
^{13}C NMR Spectrum of Compound **5f**



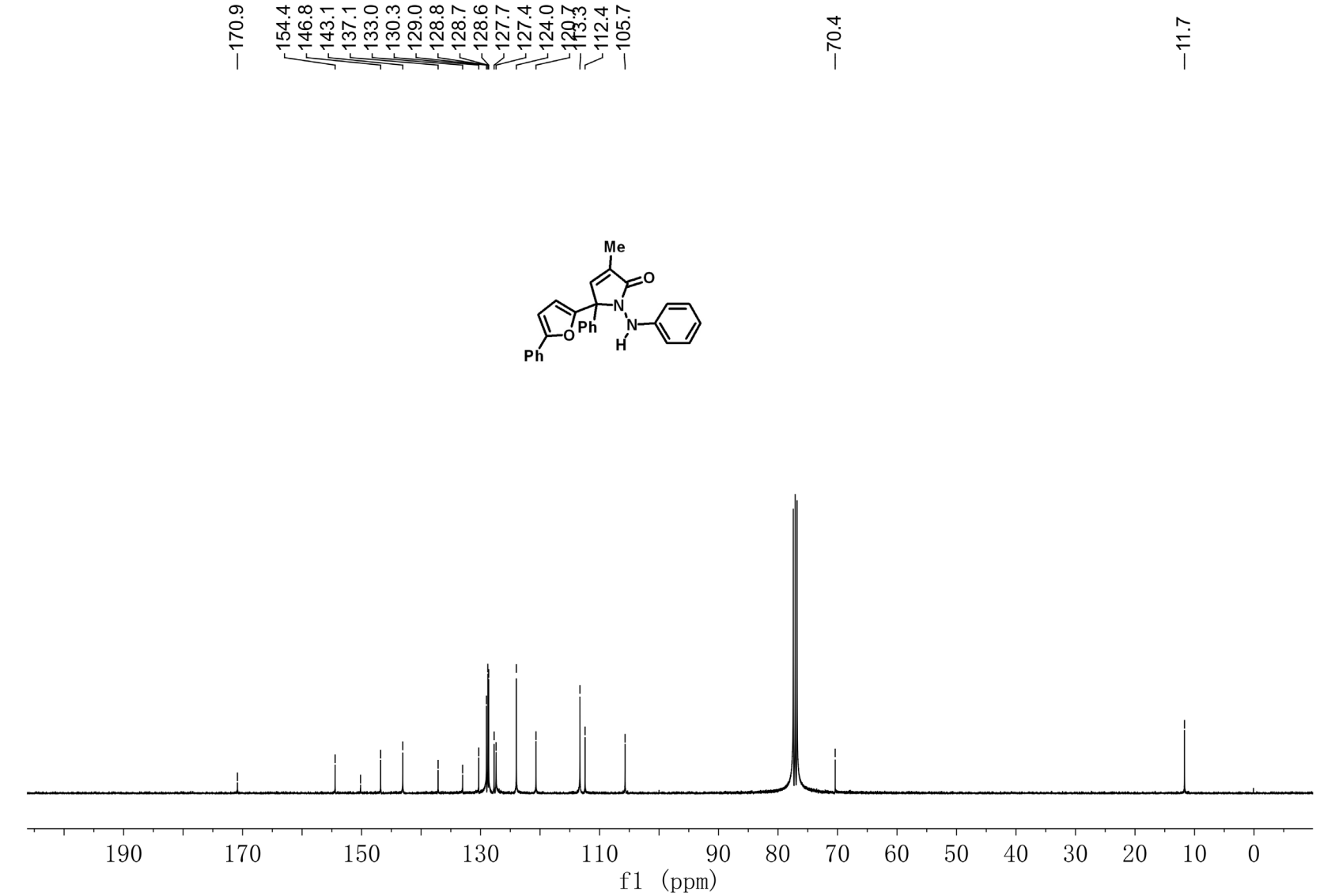
^{1}H NMR Spectrum of Compound **5g**



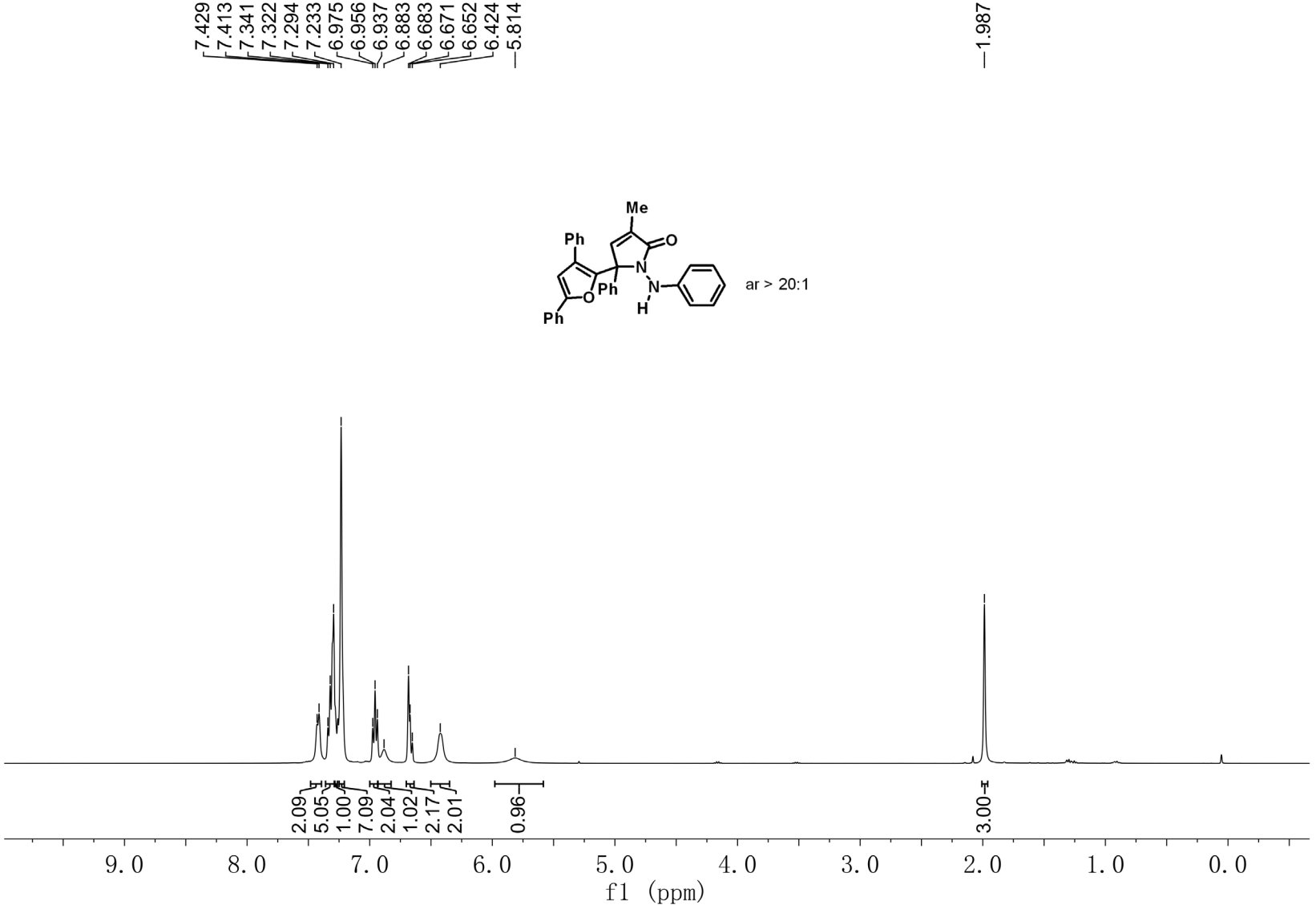
^{13}C NMR Spectrum of Compound **5g**



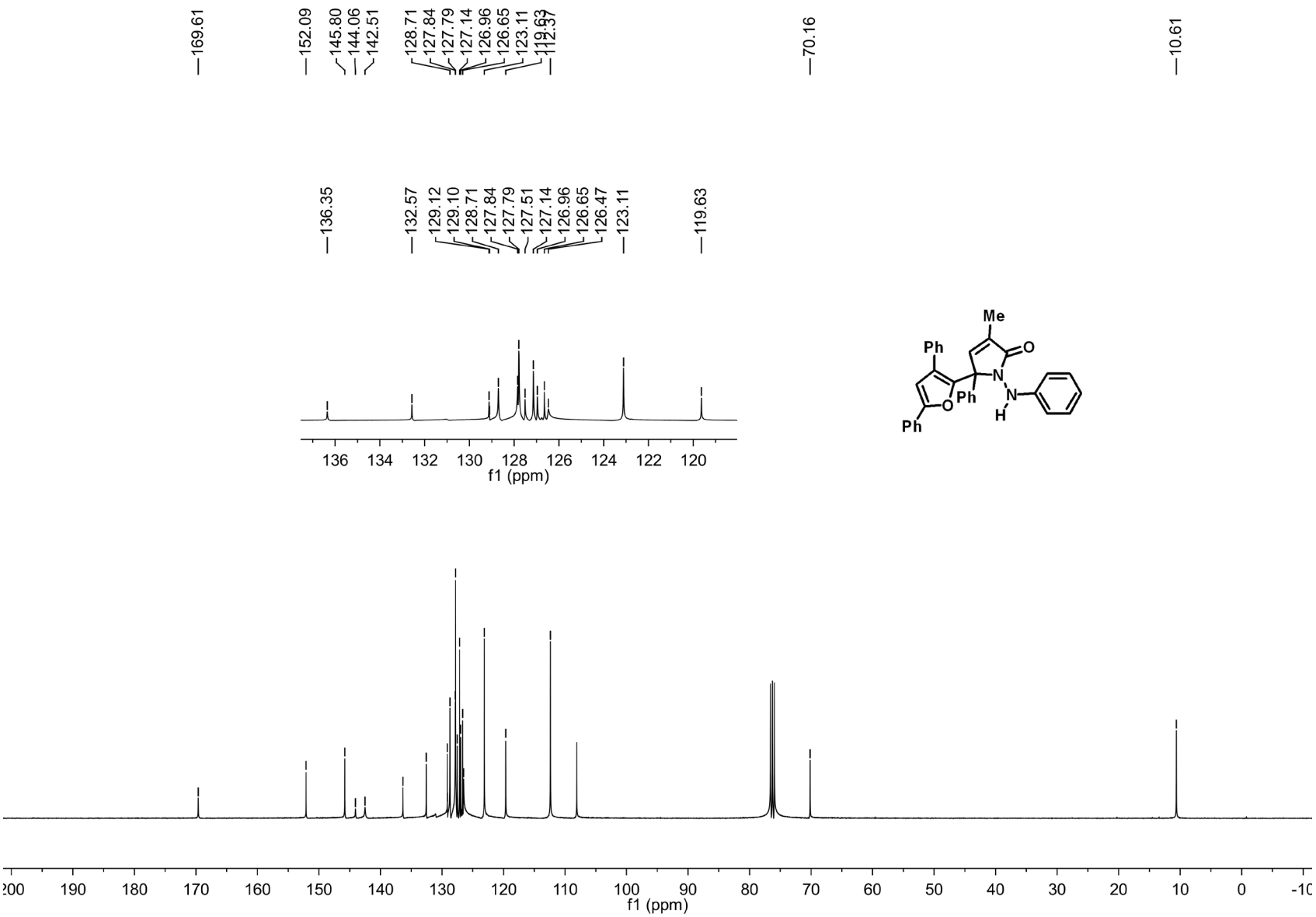
^{1}H NMR Spectrum of Compound **5h**



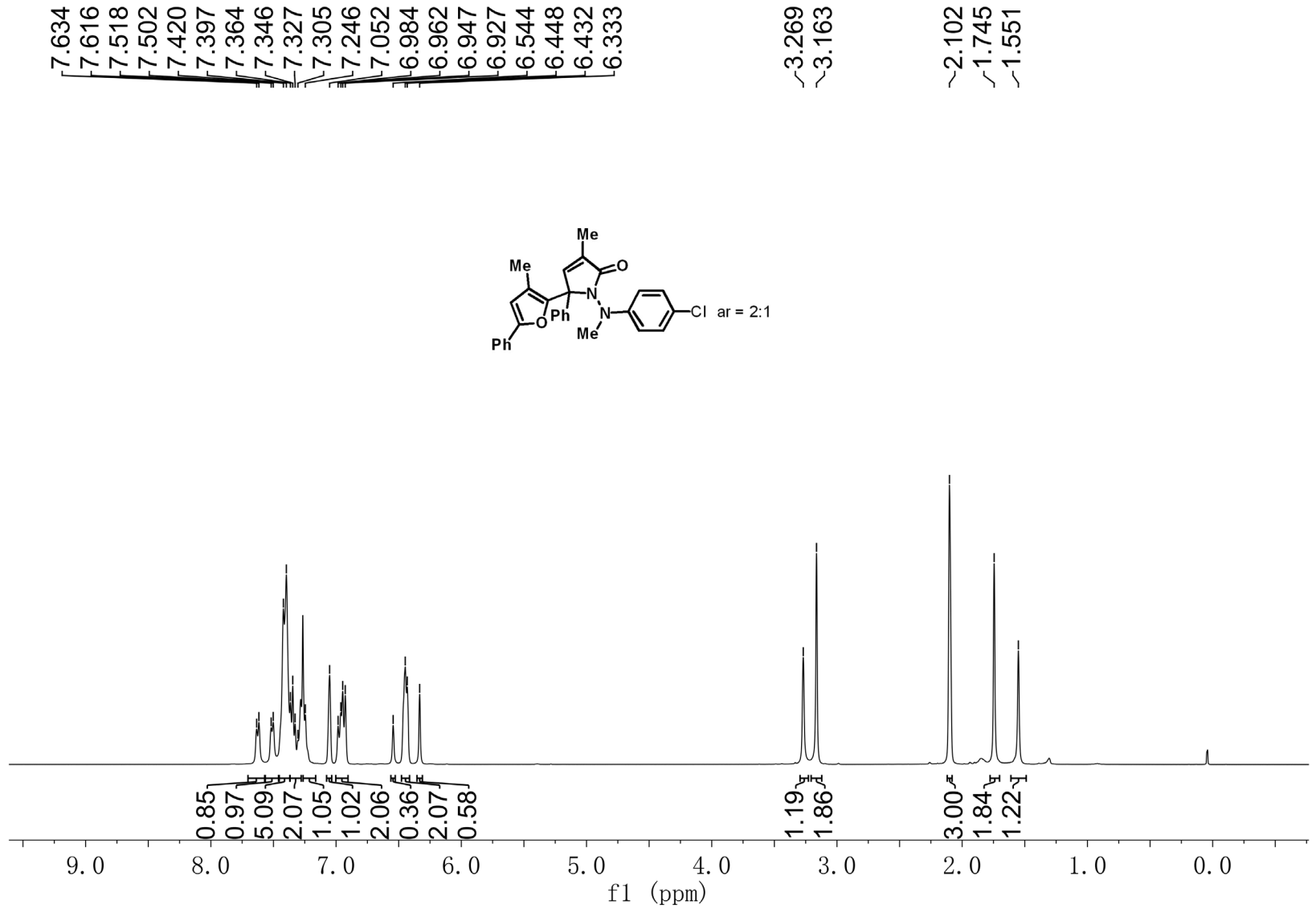
^{13}C NMR Spectrum of Compound **5h**



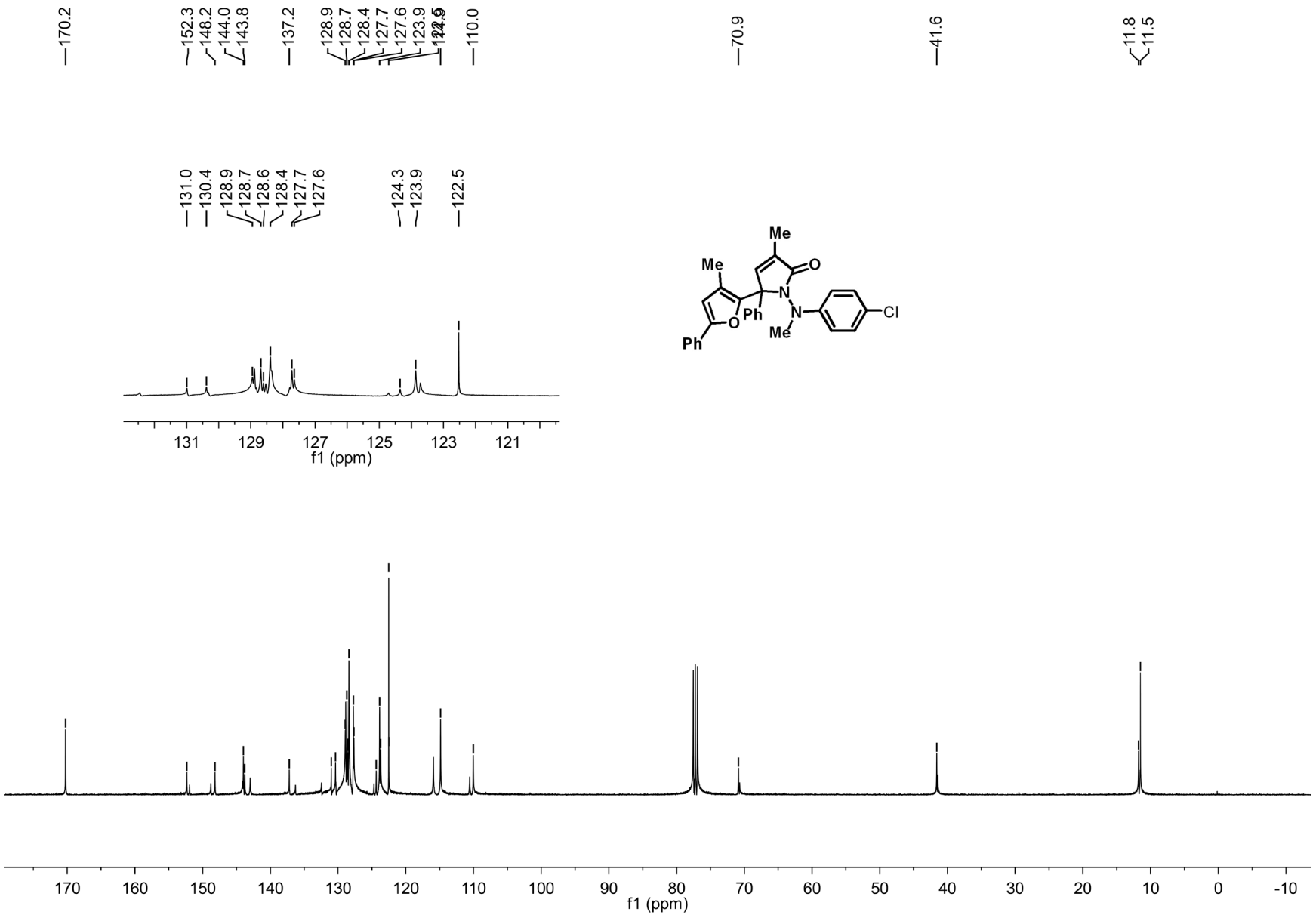
^{1}H NMR Spectrum of Compound **5i**



^{13}C NMR Spectrum of Compound **5i**



^{1}H NMR Spectrum of Compound **6**



^{13}C NMR Spectrum of Compound **6**